ABOUT FLYING

RTRUDE BACON

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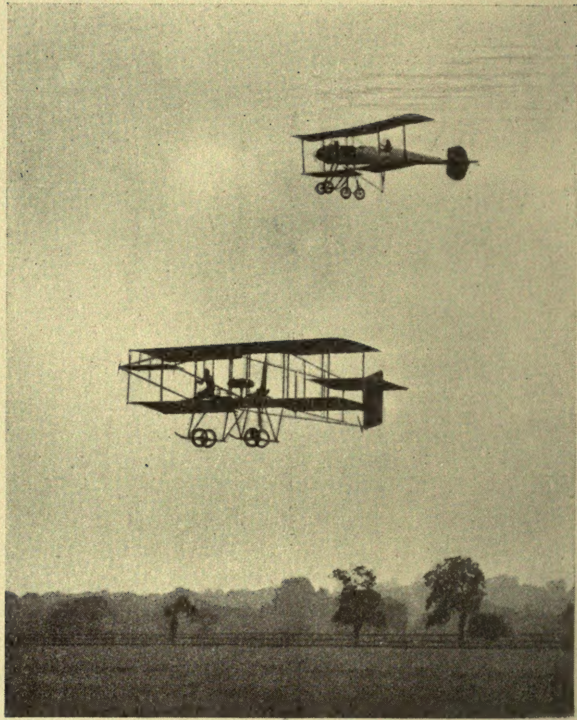

(*Flight*)

'TRACTOR' AND 'PUSHER'

Bréguet and Grahame-White Biplanes at Hendon

ALL ABOUT FLYING

BY

GERTRUDE BACON

AUTHOR OF

'THE RECORD OF AN AERONAUT,'

'HOW MEN FLY,' ETC. ETC.

WITH 27 ILLUSTRATIONS

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ALL ABOUT FLYING

CHAPTER I

HOW THE PIONEERS SET TO WORK

ONE spring day of the year 1903 there came to my old home in Berkshire an elderly American gentleman, courteous, white-haired and keen-eyed. His name was Octave Chanute, and being very greatly interested in all aeronautical matters, he had come to see some experiments which my father was making at the time with a hot-air military balloon.

And at table after lunch I remember that he talked to us of work that was being done in his own country, of many experiments that he himself had carried out in the unsolved problem of human flight, and particularly of the marvellous success of two young American brothers, who had lately achieved some truly astonishing glides on a machine that he had helped to design. He told us how they had established themselves on a lonely spot on the sandy coast of North Carolina, where a steady wind blows ever from the Atlantic; and how he himself, old man that he was, had gone into camp with them in their Robinson Crusoe isolation, and watched them drag their gliders to the top of the lofty sand-hills and then jump off and float gently to earth ; always encouraging them and helping them with new suggestions and ideas until, between them all, they arrived at a gliding apparatus that seemed a marvel for steadiness and ease of control, that had kept in the air for almost half a minute, and made glides of over 600 feet.

We listened interested, but not deeply thrilled. The fact that the names of these two brother experimenters were Wilbur and Orville Wright meant little to us. We could not realize that we were being told of the birth of man's latest and grandest achievement ; nor could we foretell that long before his death, seven years later, our guest would be enthusiastically acclaimed on both sides of the Atlantic as 'The Father of Aviation.' In quiet and subtle fashion, without blast of trumpets, do the great things of this world come to pass.

Why did not man learn to fly before ? Certainly not through lack of aspiration, for who in this world of ours has not envied the birds their wings, and longed like them to soar their way through the free pure vault of heaven ! All have desired, and very many have tried, to fly during all the long ages of the past, and undoubtedly the reason they have not succeeded earlier was because they have been led into the wrong paths of approach. For hundreds of years they beat the air with futile wings attached to their bodies like the wings of the bird they imitated, fighting vainly against the fact that man's weak muscles could never by any possibility effectively flap the great pinions which would be needed to support his too, too solid flesh in the air. For hundreds of years also they were content to listen to the jargon of 'upward attractions,' 'ethereal air,' 'little imps in earthen pots,' and the like high-sounding nonsense woven out of the brains of aged ecclesiastics immured in cloistered walls. Presently, too, they were led off down a cul-de-sac by the arrival of the balloon. The day came when men were actually lifted into the realms they longed for by great bags filled with hot air and light gases. Surely now, they said, the sky was conquered at length, and even heaven itself had come within man's grasp!

So they thought and wrote a century and a quarter ago, when first the 'lighter than air' craft came into existence, and before the disadvantages of the new invention had forced themselves into notice. And men went up in balloons with oars, and worked them madly up and down, and marvelled that the only result was their own exhaustion. And they hoisted sails hopefully out at the sides of the car which the wind caught and slewed the balloon round, yet nevertheless the course was not altered to the slightest degree. Slowly and sadly the fact was borne in upon those aerial enthusiasts of the past that their shapely giant vessels, which were to rule the winds and sail the skies, were only as corks floating idly on the sea; merely big bubbles drifting helplessly about the heavens, the sport of every breeze that blew.

More than a hundred and thirty years have elapsed since first man ascended into the sky, and the balloon has taught him many things, it is true. It has taught him facts about the atmosphere that he could have learned in no other way; it has helped him, under favourable circumstances, in warfare and exploration; it has provided him with a lovely spectacle and a delightful sport. But it has come quickly to the end of its tether. The balloon of to-day differs only in minor detail from the balloon of 1783, and is as far as ever from the conquest of the air.

The final solving of the problem came at last from quite another and wholly unlooked-for event, as we shall shortly see; but in the meantime there was one direction of experiment that was most curiously, and, as it seems now, unaccountably overlooked. From earliest days men must have observed that birds fly not only by flapping their wings, but that with outstretched and perfectly motionless pinions they can soar and glide, with no exercise of their muscles at all, merely by taking advantage of the varying currents of the wind and by reason of their perfect capacity for balancing themselves. From time immemorial mankind had flown kites, and seen them keep up in the air under the action of nothing but the wind and the restraining pull of the string. How came it that that intensely clever race, the Chinese, who spend so much of their lives kite-flying, did not realize that in their national pastime lay the germ of the great discovery? Of course, without the modern light, internal-combustion, engine practical human flight with kite or glider would still have been impossible ; but man might well have got much further than he did with such resources as he has always possessed, so that when the means of propulsion came at last it would have found him more ready to take advantage of it.

Perhaps he got further than we now know. There is more than one old church tower in England about which lingers the tradition of some daring soul, hundreds of years ago, who launched himself with wings from the summit, generally with disastrous consequence. There are well-authenticated stories of monks and others on the Continent who did likewise, one as far back as the days of Nero. Leonardo da Vinci, who, by the way, is said to have invented the parachute, made notes and sketches of marvellously ingenious wing-driven flying machines which foreshadowed the inventions of to-day. Probably there were many others, whose names and deeds are now for ever hidden in the mists of ages, who came nearer than we guess to the great discovery.

The wonderful nineteenth century dawned. The balloon had already shown its limitations. It had been proved conclusively that man's muscles alone, no matter how employed, could never give him the power of flight. Flying was universally regarded as one of those things from which man was for ever debarred by an all-wise Providence. But before ten years had passed there arose a pioneer in the person of a Yorkshire baronet of scientific tastes—

Sir George Cayley. In those days the steam-engine, with all its untold possibilities, was just coming into existence, and to Sir George, gifted with a foresight a hundred years ahead of his time, it seemed that here lay the solution of the problem. Man could not fly by his own unaided strength, because his power was so small in comparison to his weight; but directly he could build an engine that would generate more power in proportion to its weight than a man could produce with his muscles, then there was no real reason why he should not fly with it.

This conception is the bed-rock of the whole matter, and Sir George Cayley was the first to arrive at it. Looking onward into the future, he outlined the principle of the gas-engine which was not to be invented for another fifty years. Studying the birds, he argued that the wings of a flying machine must be curved and not flat, that an elevator in the tail would be needed as well as a rudder. A true seer, he pointed out facts and discoveries that later generations have toiled laboriously to find out anew. He himself experimented with flying machines which incorporated, it is said, every single important principle now accepted by the aeronautical engineer. About his old Yorkshire home, near Scarborough, there survives the tale that one day he fitted some crude form of internal-combustion engine, driven by gunpowder cartridges, into one of these flying machines, and then put his coachman into it to run it along the ground. But presently, to everybody's surprise, the thing began to lift, and the poor aviator was so scared that he hastily jumped out and broke his leg in so doing. True or not, it is a pleasant little legend, and one would fain believe in the humble coachman pilot of a hundred years ago who was the nameless first victim of aviation.

But the light engine which was to make flight possible was long in coming. Nearly forty years elapsed before we arrive at the next couple of pioneers, Henson and Stringfellow, two engineer friends living at Chard in Somersetshire, who entered into partnership to make a flying machine, Henson being chiefly responsible for the design of the aeroplane, Stringfellow for the light steam-engine which was to drive it. Enthusiastically they strove to run (or should we say 'fly'?) before they could walk, took out a patent and formed a company while yet their invention had not even materialized. The model refused to fly, the public declined to subscribe, Henson married his landlady's daughter and emigrated to America discouraged and impoverished, and the company ignominiously collapsed. But still in old print-shops, village inns and cottages, can be seen pictures of the machine in full flight, with Union Jack at the helm, proudly sweeping its way across the sea to distant lands.

Ridiculous no doubt, and yet this old print is well worth studying, and so is the copy of the actual machine that hangs in the South Kensington Museum, for there we have the prototype of the modern monoplane, with its long and narrow wings, elevator tail containing the rudder, pointed prow and wheels for starting. In almost uncanny fashion the suspension of the wings anticipates the famous Antoinette aeroplane of seventy years later, which machine indeed the quaint old model irresistibly suggests. But in one particular the design fell behind the discoveries of Cayley—the wings were flat and not curved, a fact which helped largely to account for its lack of success.

After the departure of Henson, Stringfellow still continued his flying experiments, and actually succeeded in producing the first engine-driven aeroplane that ever flew. True it was only a model of 10 feet span, driven by a tiny steam-engine, the whole weighing but 8 lbs.; but the triumph was none the less on this account, and its flight of 40 yards marks another milestone in the history of aviation.

And so does the work—still another twenty years on—of Francis Wenham, an English engineer who had spent some time in Egypt, and while there had studied the flight of certain of the African birds to such good effect that he arrived at new facts of the very utmost importance. For he it was who first pointed out that the effective part of a wing in flight is at the front, that the strongest flying birds possess long narrow wings instead of short broad ones, and that it is in length and not breadth of plane that increased lifting power must be sought for in a flying machine. Moreover he showed that because extremely long and narrow planes are difficult to deal with and to build strongly, the long planes can be cut into two or even more lengths and mounted one above the other, at a suitable distance apart, with practically no loss of efficiency. Here at once in Wenham's discovery we have the inception of the biplane, even as Henson's model shadowed forth the monoplane, while Sir George Cayley's prophetic brain fathered both. Let us English men and women, who love to carry self-depreciation to such a hysterical pitch that we consider it bad form to own to any national triumph whatsoever, and who take it as a matter of course that the foreigners have beaten us in the great discovery of flight—let us nevertheless in all justice recollect that although, somehow, we allowed the consummation to escape us, they were English brains in the first instance who made that discovery possible.

So the years sped by, the nineteenth century had nearly passed away, and to the man in the street flight appeared as hopelessly remote as ever. But to a small, yet ever-increasing, band of enthusiasts it seemed that dawn was near breaking. The eighteen-nineties arrived, and all over the world men were working feverishly. In this country Mr. Horatio Phillips was experimenting on the most efficient forms of planes, and quietly and unostentatiously doing 'spadework' that only the aeroplane constructor of the present day can estimate at its full value. Sir Hiram Maxim was turning his giant brain from guns to flying machines, and actually, in 1893, produced a perfect leviathan of an aeroplane, weighing over 3 tons and driven by a steam-engine of 360 horse-power, which was for those days a miracle of lightness. Unfortunately this stately craft had but a short life, for, impatient for the heavens, it rose into the air before it was intended to do so, and so brought about its own destruction in the very moment of its success.

In America, Professor Langley was flying engine-driven monoplanes from a house-boat moored in the broad waters of the Potomac, his patient and all-important work deserving better success than it achieved. Through lack of funds he was obliged to cut short his experiments after a heart-breaking series of accidents, and it is said that disappointment hastened his death. Eleven years later poetic justice was done to his memory by Glenn Curtiss, the famous American aviator, who repaired Langley's old machine and made an excellent flight with it, thus vindicating, alas too late, its author's work as a true pioneer.

In France, Ader, a well-known electrician, produced three fearfully and wonderfully made machines, the first of which, it is stated, actually achieved a flight or glorified hop as far back as October 1890, years before Maxim or anyone else had got into the air; while the last and most successful, 'L'Avion' by name, flew 300 yards in 1897 before a committee of army officers appointed by the French Government. To begin with the Government assisted financially in the work, which, first to last, cost Ader a million francs; but in the end they tired of him, pronounced him a crank and threw him over, a deeply disappointed man. Nevertheless he had his revenge. The day came, some fifteen years later, when the French nation would have given many million francs to undo their mistake and prove to the triumphant Americans that they were indeed the first in the field of flight. Tardy justice was meted out to the aged aviator, and in graceful acknowledgment of his work the French military aeroplanes are known as 'avions' in remembrance of the nightmare machine, with wings like a bat and propeller blades like feathers, that feebly fluttered from the ground so long ago.

But there were certain men who grasped the fact that there was yet a shorter and surer path to success. So far would-be flyers had begun with the hardest task of all, the getting of their machines off the ground. All their skill and strength were expended in this effort, so that when they rose in air at length they lacked the knowledge and experience to keep them there and the result was continual disaster. 'To conceive a flying machine is nothing; to construct one is little; to fly is everything.' These were the words of Otto Lilienthal, an engineer of Berlin, and in proof of his belief he started where men might have started so long ago, with learning to balance and glide with a framework of wings attached to his body, launching himself from a height and 'planing' to the ground. Rapidly he grew in skill and knowledge, adding larger wings and a big curving tail to his glider, making it ever more stable and easier to control, learning ever new facts about its lifting power and design. So proficient did he become that he could glide for 400 yards at a time, and he was already contemplating putting an engine into his apparatus when, one day, some part of his machine gave way in the air, and he fell 50 feet to the ground and broke his back.

Long before this happened (in 1896) he had an English disciple in Percy S. Pilcher, a young engineer who also laboured enthusiastically with gliders of somewhat different design, and continued, by their use, to add to the general knowledge of flight, until he too fell from a height and was killed. Thus died two early martyrs of aviation, their lives not sacrificed in vain, but given for that great triumph whose arrival their work has so greatly hastened.

Lilienthal's gliding experiments fired other pioneers all over the world, among them Octave Chanute and the Wright Brothers in America, as we have seen. Lilienthal and Pilcher had used monoplane-shaped gliders and balanced them by swinging their bodies, which dangled below. The Americans found that much better results could be obtained with a biplane, or two-decker form of craft, on the lower plane of which the aviator (only he did not yet know himself by that name) lay prone and still, keeping his balance by manipulating the machine and not himself. This again was a tremendous advance.

In Australia also record-making work was in progress, for there Lawrence Hargrave was making experiments which culminated in the invention of the famous 'box-kite,' prototype of innumerable flying machines. Thus everywhere men were labouring, in different ways, and with independent methods, at one great problem. The work was growing apace. It needed only some last great impetus which should unite the results already attained, and break down the last tottering barrier to success.

And it came, in the fullness of time, in an unlooked-for fashion, from a totally unexpected quarter. In those years there began to be seen about the roads unfamiliar horseless vehicles at which the rustic gaped in incredulous amazement. Little jeering boys stood in circles round men who grovelled in the mud beneath complicated apparatus which refused to work. Millionaires sat patiently, hour after hour, in the hedge contemplating the new toy which had stranded them hopelessly the other end of nowhere, and the smell of burnt petrol grew familiar in the land. Fitful, capricious, imperfect as it first was, the motor-car had arrived, and with it had brought that wonderful, light, petrol-driven, internal-combustion engine that Sir George Cayley had dreamed of a century before, and that now, at long last, even as he said, made flight possible. Santos Dumont put one of these early engines into a balloon (in 1898) and behold the modern airship. Wilbur and Orville Wright five years later fitted a petrol motor of their own construction into their most successful type of glider, and on December 17, 1903, a flight was made of 852 feet. Before two years had elapsed they had flown 20 miles. The aeroplane had arrived!

CHAPTER II

WHY AN AEROPLANE FLIES

THERE are certain desolate and terrible tracts of the earth's surface where there are no birds and no flying insects; no bees or butterflies hover over the flowerless ground, and no feathers beat the empty air. Supposing this condition had obtained over the whole world, supposing man had never seen or heard of flight of bird or insect, would he have conceived of it as being even possible?

Probably not. Let us imagine our world exactly as it is, but bereft of every form of flying creature—that is to say, of nearly all the birds, a great proportion of the insects, and just a few of the fish and little animals. Into this singularly unattractive world that we have pictured the thought of flight could hardly have entered. Its inhabitants would know all about the action of gravity; they would know that if they fell from a height they would be drawn relentlessly downwards through the yielding air; how could they conceive that any body heavier than air could possibly be kept afloat in the atmosphere except, perhaps, by such means as a balloon?

And yet man is marvellously ingenious, and has worked out for himself more difficult problems even than this. Perhaps a philosopher of this birdless world watching the dead leaves whirled aloft by the autumn breeze, a yachtsman with carefully set sheet close-hauled, a miller contemplating his revolving sails, a rueful motorist in a swiftly moving car whose hat had just been carried high aloft from his head, all or any of these might have guessed the secret. Or if not, then surely it must have occurred to some Isaac Newton watching his little son fly a kite—an object heavier than air, and yet capable of rising and sustaining itself above the earth.

Yielding and attenuated as it is, there is a power of resistance in the air with which we are all familiar. We feel it on a windy day when we stand still and the wind blows upon us. We feel it on a still day when we rush rapidly through the air in a motor-car, and the wind we feel is the wind of our own motion. On these and other countless familiar occasions this air resistance is exerted horizontally; but with a suitable contrivance it can be employed to exert an upward force, and here lies the secret that birds and insects, and millions of years later man himself, has discovered, the secret of flight.

The condition under which the resistance of the air can be made to afford its greatest upward lift is when a light, flat (or nearly flat) surface set at a small angle is driven rapidly forward. Newton himself first formulated the law that the pressure exerted by a fluid (and air is as much a fluid as water) is 'normal'—that is, at right angles—to the surface. Make a little picture in your mind, or on paper if it suits you better, of an upright plane with the pressure of a fluid (in this case the force of the wind) acting upon it. Obviously, as Newton said, it will tend to move forward in a direction at right angles to itself—that is, horizontally. But supposing the plane is not upright, but at an angle to the wind that blows upon it, then according to our law it will still tend to move forward in a direction at right angles to itself, which means that it will rise, or try to rise, at an angle into the air. This is the great principle of the inclined plane, the fundamental principle that raises every bird and insect and kite and aeroplane from the ground.

By way of parable let us picture a fine afternoon with a fresh breeze blowing steadily, and we ourselves upon some open common not far remote from the haunts of man. It is Saturday afternoon, and on the grass are two or three groups of children busy with their kites. One schoolboy has a large square box-kite, another the 'fin-bat' variety, with a little subsidiary plane standing out at right angles to the main surface; a child of smaller size, but equally enthusiastic, toddles about with the old-fashioned familiar toy with a tail of knotted paper attached. Sympathetically, for who does not love a kite? we watch their efforts, and see the big box-kite, deftly thrown into the air, catch the wind and rise higher and higher into the sky until it strains our eyes to distinguish it against the blue. The 'fin-bat' gives some trouble at first, for the string is attached in the wrong place and the thing swoops and curves and plunges to the ground until the balance is adjusted, when it rises triumphantly to its limit, which is not, however, as high as that of the box-kite, because, as its owner is anxious to explain, not being so large, it has not the strength to lift so great a weight of string.

But presently the rival meets with disaster ; for the kite-string suddenly breaks, and the kite, released from the pull that kept it at an angle to the wind, is promptly blown right over, and falls headlong in a distant field with disastrous results. Meantime the toddler, after much exertion and fruitless endeavour, becomes loudly tearful at his lack of success, until a compassionate elder, by knotting some more paper on to the tail of his kite and thus altering the weight and balance, induces it to rise to modest but satisfying altitudes. As the afternoon wears on, the wind, which is falling, becomes fitful in its gusts, the kites swoop earthward, and the boys run over the ground, pulling their kites by the strings behind them, the motion thus imparted to the kites themselves making up temporarily for the lack of motion of the wind.

But the breeze dies with the day, the children gather their toys and depart homewards, and next we see come out on to the common a young man with a model aeroplane, clearly of his own design and construction. Carefully he winds the stretched elastic which revolves the tiny propeller, carefully he launches his craft into the air, and his face beams with satisfaction when after a few abortive attempts and a few minor adjustments—a wing straightened out, an elevator tip turned upwards—the dainty little toy springs forward and skims gracefully through the air, some 300 yards and more, until, the force of its untwisting elastic expended, it sinks gently on to the grass.

Twilight falls, and we turn our steps towards home, but even as we do so comes upon the wind a faint but ever-increasing murmur, a deep and steady hum growing to a roar, that resembles the noise of a powerful motor-car, and yet is unmistakably different. There is a cry of 'An aeroplane!' and the strollers on the common turn their faces eagerly upwards as there swoops across the sky, proudly and steadily, with infinite dignity of bearing and grace of swift unswerving flight, a large biplane flying high; appearing first as a couple of parallel lines against the blue, and then as it nears, revealing its tapering body and full spread of white wings—a thrilling and beautiful sight that familiarity never robs of its charm.

In one short hour we have seen three examples, in progressive sequence, of the flying machine. Kites have been flown from time immemorial, elastic driven models were introduced by Penaud forty years ago, aeroplanes are the invention of to-day, but the fundamental principle is the same in all three: the light supporting surface set at an angle against the force of the wind. Only whereas in the kite it is the wind of heaven that supports the plane, and the pull of the string that keeps it at the right angle, in the power-driven machine it is construction and human skill that maintain the angle against the self-made wind of the swift onward motion.

The requisite angle, known as the angle of incidence, is a matter of prime importance. Naturally the more you tilt your plane upwards the more resistance it will offer to the air, and the more power you will need to drive it along. This air resistance is exerted horizontally, and the aeroplane constructor has a sort of slang term for it: he calls it 'drift,' in contradistinction to 'lift,' the force that would raise the plane vertically upwards. As we have seen, a plane set at an angle against the wind has a tendency to 'lift' as well as 'drift,' and as a compromise between the two goes slantwise up into the sky. The more 'lift' it has and the less 'drift' the steeper will be the angle at which it rises. There is both lift and drift in the flight of every aeroplane; but the aeroplane designer aims at obtaining the least possible amount of drift to the greatest amount of lift in his machine, and he does this, in the first place, by setting his planes at a very small angle to the horizon.

But he does more than this: he makes his planes of a particular shape. It was Sir George Cayley, as we have seen, more than a hundred years ago, who first pointed out, from the study of the wings of a bird, that more lifting power could be obtained from an inclined plane by making it not flat but arched, with its front edge curved downwards, or as we now say, 'cambered.' Later investigation has proved this point to be of the very vastest importance; in fact it is certain that but for the discovery of the properties of the 'cambered plane' we should never have risen into the air at all. The history of the discovery of flight supplies many useful parables on the necessity for the theoretical man and the practical man to work together in the paths of progress. The mathematician, with pencil and paper, demonstrates irrefutably, from the laws of motion, that flight is impossible because more power is required to raise the planes than could ever be profitably employed. (According to Newton's laws alone a swallow would need the strength of a man to move at the speed it actually attains.) Meantime a Lilienthal or an Orville Wright builds himself a glider, practises with it down a hill, and presently proves that flight is already within man's grasp, because by simply bending his planes he gets a lifting power out of them at which the theorist could not even guess.

Exactly why a cambered plane lifts better than a flat one is only just beginning to be understood, and is still matter of experiment and discussion. It is due entirely to the behaviour of the air. We have all of us noticed the infinitely complex eddies and currents set up in water by passing objects—the blade of an oar or the hull of a boat. We have all watched the broad path of churning waves that marks the trail of a steamer across the sea. We ignore, because we cannot see them, the currents and eddies that passing objects are for ever causing in the air, vastly more complicated because air is so vastly more unstable. But if these water eddies are sufficiently important to have to be carefully reckoned with, as we know is the case, in designing the hull of a battleship, we can guess what great effect the air eddies must exercise upon a light aeroplane in swift motion aloft, and how all-important it is to understand their action.

In making diagrams and pictures which are to represent the flow of currents of air or water, it is customary to indicate them by drawing a number of long parallel lines in the direction in which the current is flowing. In similar fashion we may consider, for convenience sake, that water or air is composed of an infinite number of minute threads of fluid arranged regularly side by side; and for these hypothetical threads there is a recognized term —the 'stream-lines.' It is the breaking up of these stream-lines which causes eddies and resistance when an object is moved through them. To reduce the resistance to a moving body as far as possible it is necessary to make the body of such a shape that the stream-lines—either of air or water—flow round it smoothly and unbrokenly, and the correct form of this much-to-be-desired 'stream-line shape' has been the subject of endless experiment. One result has been to prove that Nature, as usual, has been ahead of us, for in the end, after all his experiments, the designer finds he cannot do better than shape his torpedo like a fish, while every year sees the form of the body of a monoplane more nearly resembling that of a bird. A stream-line shape travels blunt end foremost, and tapers smoothly off towards the tail. This is speaking broadly. Latest researches have revealed the subject as infinitely more complex even than first supposed, and it would appear as if correct stream-line shape varies with the speed at which the object travels. There is still much to be learned in this direction, and the subject becomes yet more difficult and complex when we consider the motion of the stream-lines of air about a cambered plane driven rapidly forward, and the effect of the eddies thus set up.

Investigation reveals a curious state of affairs. Formerly it was considered that the reason why a cambered plane lifted better than a flat one was because the concave under side could grasp and force downwards a greater handful of air (if one may so describe it) and so obtain an increased support. Undoubtedly this is the case, but it is not the whole truth or even half of it. Only about one-third of the increased lift is due to the under side; the other two-thirds, wonderful as it may appear, are the result of the convex upper side. The vortex or eddies set up in the air by the rapid progress of the front of the plane cause a vacuum over the top, and the plane, if properly curved, is actually sucked upwards and forwards with a force powerful enough to have great effect upon its lifting power.

If we examine the lifting surfaces of a modern aeroplane—commonly called the planes of a biplane and the wings of a monoplane—we shall see that they are not cambered symmetrically. That is to say, the curve of the lower surface does not follow that of the upper, but there is a distinct ' hump ' near the front, or ' entering ' or ' leading ' edge as it is called, and a tapering away towards the rear or ' trailing ' edge. Recently Mr. Howard Wright, a famous pioneer of aeroplane design, who has worked on the problem since the days when his American namesakes began their flying experiments, has evolved the ' double-cambered ' plane, where the under surface is concave as usual, but the upper has two, not quite symmetrical, ' humps,' one behind the other, as if two narrow cambered planes were joined together lengthways. By this device he expected to add largely to the all-important suction action, and results have amply justified him in his belief, for he obtains a lifting power far in excess of that yielded by the most effective single-cambered plane in existence.

But in addition carefully to shaping our planes and setting them at a well-considered angle, we have also to drive them sufficiently rapidly through the air. The support which the planes gather from the resistance of the air can only be obtained by their continually passing over fresh and undisturbed areas. The quicker they travel the more support do they find. There is more than meets the eye in that very simple answer to the question, ' Why does an aeroplane keep up in the sky? ' ' Because it hasn't time to fall down.'

And in this rapid progress it is the entering edge of the plane which bears the brunt of the task. As the plane passes through the atmosphere the front of it enters continually upon new regions of undisturbed air which it presses down and forces into all sorts of currents and eddies. The rear part of the plane which passes over the same air immediately afterwards gets the 'back-wash' from the front, and so having only disturbed air to press on, is not able to obtain so much support from it. Therefore, as Wenham pointed out half a century ago, long narrow planes are more efficient than short broad ones; and to increase the lifting surface of a plane you must add to its 'span' or length, and not to its 'chord' (which is the correct term for the width disregarding the camber). The proportion of the span of a plane to its chord is known as the 'aspect ratio.'

As has already been said, these long narrow planes can be made in two lengths and mounted one above the other, as a biplane, with no great loss of lifting power save a certain amount due to the fact that the planes have now four ends instead of two, and the air has ever a tendency to slip out from under them. Of course the planes must be placed at such a distance apart that the air disturbances set up by the one do not seriously affect the other. It was the Wright Brothers who first determined from experiment that the distance between the planes of a biplane—the 'gap,' as it is termed—should be the same measure as the chord, and this precedent is generally adhered to.

As we have seen, an aeroplane travelling at high speed gets much more lift out of the air than one travelling slower. It does not need, therefore, if it is of similar weight, to have such large wings to support it. Other things being equal, the smaller the planes, the greater the speed. Blériot and others before some big race have literally clipped the wings of their birds, to make them fly faster, until their machines have been likened to an engine with two visiting cards attached. The speed of an aeroplane also varies with the 'angle of incidence' of the planes, for upon this, as we know, depends the amount of resistance they will offer. The speed, the weight, and the angle of incidence are all mutually dependent upon each other, so that an aeroplane of a fixed weight flies at a fixed speed at a fixed angle, and you cannot interfere with one of these things without altering another. Increase the speed without altering the weight or angle, and the aeroplane, instead of going quicker, will rise in the air; decrease the speed alone, and it will descend.

As a matter of fact, an aeroplane in the air is continually altering its angle of incidence. The greater the speed the less the angle, and by depressing his elevator the aviator can make his wings lie flatter and flatter in the air. In early days when engines were only just powerful enough to raise their ill-designed craft from the ground, and pilots and constructors had not yet attained to present wisdom, it was held that every aeroplane had but one flying speed which could be varied only within very small limits. Nowadays, with carefully cambered wings, well-considered construction, and powerful engine with plenty of reserve horse-power, the aviator finds he can vary his speed 50 per cent. and over. A

(*The Aeroplane*)

'SOPWITH' SCOUT

36 to 92 miles per hour

Sopwith biplane can fly as fast as 92 miles an hour, and as slow as 36. An Avro can range from 83

(*Flight*)

AVRO TRACTOR BIPLANE

30 to 83 miles per hour

miles to 30. Moreover in the most efficient machines the variation is brought about simply by throttling down the engine. The 'Wight' sea-plane, for instance, with the double-cambered planes already referred to, can be varied in speed from 80 miles an hour to 36 without even touching the elevator; driven, in fact, precisely as if it were a motor-car. The explanation is that the carefully cambered wings are efficient over so large a surface that the effect is the same as that obtained by varying the angle with the elevator.

In any case, automatically or otherwise, the planes lie flatter in the air as the speed increases until, at the greatest speeds, the leading edge may be actually lower than the trailing edge. When this happens the plane is said to be at a 'negative angle.' Of course there is a limit in this direction. An aeroplane that is being forced to fly horizontally at a speed beyond what it is designed for begins to 'hunt' —that is to say, it has a continual tendency to dive downwards or shoot upwards, and so pursues a disconcertingly wavy track across the sky.

In speaking of the speed of a flying machine we must always bear in mind that we mean speed in relation to the air it is passing through, and not the ground that it is covering. Imagine a 20-mile wind blowing over an aerodrome, and an aeroplane travelling at 50 miles an hour flying dead into it. Obviously to a man standing underneath it is only passing by at 30 miles an hour. But wait until the machine has rounded the pylon at the end of the course, and comes tearing back with the wind behind; then the observer will see it flash over his head at

70 miles an hour, and yet all the while its own speed has never varied.

In the bygone days of aviation—which are really very recent days as far as mere time goes—how often has one heard the remark, 'Ah! but flying will always be terribly risky work because, if your engine stops while you are in the air, where are you?' (The speaker implying that he knew quite well where you would be—smashed to little bits on the ground.) The particular brand of old gentleman who talks like this is even now not wholly extinct, but he is wholly wrong in his premises. To his incorrect way of thinking it is the forward motion of the aeroplane that alone supports it in the air, whereas, as we now know, it is supported also by the size, shape and adjustment of its planes. When a parachute is dropped from a balloon it falls first like a stone until the pressure of the air underneath it begins to open it out as an umbrella. Beneath its wide, curving surface it catches and compresses a large quantity of air, until the resistance of this air-cushion becomes equal to the rate of fall, or acceleration, and after that it no longer falls quicker and quicker but descends at an even rate. The planes of an aeroplane are not, of course, large or light enough to act as parachute to the great weight of a flying machine; but the aeroplane is none the less safe on that account. An aeroplane with engine stopped becomes simply a glider, possessing its own gliding angle which varies with the particular machine; and as long as it is put into and held at this particular angle (and a well-designed aeroplane will take and keep its gliding angle of its own accord) it will glide down from the sky at a speed dependent upon the resistance it offers to the air and which does not increase. This gliding flight with engine stopped is 'vol plané,' and we shall enlarge upon it in a later chapter.

So far then we have gone some considerable distance in learning how to make a flying machine. We have learned that in order to fly we must provide ourselves with light supporting surfaces, or planes, set at a small angle to the horizontal and driven rapidly through the air. We have also realized that to get the greatest lifting efficiency out of these planes we must curve them in a particular fashion and construct them of a particular shape. But we have to do more than this; much more. We have not only to get our flying machine into the air but we have got to keep it there. We have got to prevent it from rolling over sideways, from pitching downwards on its nose, or sliding backwards on its tail, or combining most of these motions in a spiral spin. We have got to make it capable of withstanding the buffeting of the winds, the sudden side gusts, the unforeseen eddies, the rising and descending currents, the different densities of stratas of air that it will meet with in its passage through the sky;—in a word, we must give it stability. We must also provide it with means for steering its course in the air.

It was the birds who first pointed out that the best way to prevent pitching up and down in the sky was to have a tail sticking out at the back. The pressure of the air on a smaller plane fixed some distance behind puts the brake on any oscillations in a vertical direction that the main planes may indulge in; and within certain limits the further back the tail is placed the more effect does it have. The form of the tail plane and the angle at which it is fixed are matters of prime importance to the balance of the machine. Although the difference is so small that the fact may not be visible to the eye, the tail plane is not set at the same angle as the main plane, but at a lesser one. This fact helps to give lateral stability, and is known as the 'fore-and-aft dihedral.' In some machines the tail plane is cambered like the wings. It is then said to be a 'lifting' tail, for it helps to support the weight in flight; in others it is flat, and therefore 'non-lifting.'

Practically all aeroplanes nowadays have tails. The original flying machines made by the Wright Brothers in America—the first aeroplanes that ever flew—had no tails, and were kept horizontally stable merely by working the elevator (a large biplane one) placed in front. The old Wright machines, therefore, were lacking in 'natural stability,' and were in consequence hard to learn to fly; although their pilots claimed for them that once mastered, they were easier to control than any others. Nevertheless the Wright machines have since come into line with the rest, and have done away with elevator in front and put it as a tail behind.

Every aeroplane possesses an elevator—a smaller movable plane, or planes, placed horizontally out at the front or back of the main planes. By raising or depressing the elevator the nose of the machine is tilted upwards or downwards; the angle of incidence is thus slightly altered and the machine rises or falls in the air. In early biplanes this elevator was almost invariably put in front, or there were two elevator planes, one in the front and the other in the tail. Modern practice, with a few notable exceptions, has been to take the elevator away from the front altogether and place it as a flap in the tail. In monoplanes, of course, the elevator has always been in the tail.

To steer to right or left in the air an aeroplane has a rudder of one or more small vertical planes, also placed in the tail, which acts in the same fashion as the rudder of a boat. To prevent an aeroplane from rolling over sideways—that is, to provide it with lateral stability—has proved a specially difficult task, and a variety of means have been tried. The early French constructors believed in having a number of upright surfaces which should offer resistance to the air when the machine tended to roll over. If we look at pictures of the first French biplanes that ever flew—the Santos Dumont and the Voisin (it is not ten years since they were built, but they look as out of date as the pterodactyl)—we shall see that the planes were all boxed in and divided into compartments by these 'panels,' as they were called. But the cure proved worse than the disease, for the panels not only offered great resistance to turning, but, with a side wind, they caused the aeroplane to veer from her course and progress crab-wise through the sky. So panels went by the board.

Another method by which they endeavoured to get the same effect was by tilting the planes upwards from the middle so as to form a very shallow V with the body of the machine. This is called the 'dihedral angle,' and by its means an increased side area is afforded. It is used in modified form in many machines of to-day; sometimes the lower plane only is made V-shaped, sometimes the ends of the upper planes are turned slightly upwards. Large panels are no longer employed, but the question of 'side areas' is an all-important one. If there is a big rudder in the tail and no upright surface in the front, the machine may not steer properly, but will tend to spin round in a spiral. The aeroplane constructor has therefore to consider his side areas very carefully, and provide for them by such means as making the front of the body deep and covered-in; or by affixing small fins where they may be most effective. The old American Wright machines, for example, had tiny upright planes known as 'blinkers' in the front elevator, and when the elevator was put at the back it was found that the blinkers had still to be retained, and so they were placed on the front of the skids.

Further to assist in its balancing every aeroplane is provided with one of two special means of control —'warping' or 'ailerons.' The Wright Brothers were the first to employ the warping device on their original gliders. They made the rear edges of their planes flexible, and connected them with a lever in such a manner that when the machine tilted down on one side the pilot was able to pull down or ' warp ' the edges of the planes on the end that was depressed; while the same movement twisted or warped upwards the edges of the end that tilted up. In this fashion more wind pressure was brought to bear on the falling end, tending to lift it, while less pressure was exerted on the rising end, causing it to descend, and so the machine was made to keep an even keel. It was in the carrying out of this warping action that the Wright Brothers claimed, and won, their famous patent, the subject of so much discussion and litigation. The fact that the same patent had been employed by the birds since time immemorial has had no legal bearing on the case.

The same effect as that produced by warping the wings may be obtained by providing them with ' ailerons,'—movable flaps fixed at the rear ends of the main planes. These flaps are hinged portions of the planes themselves which can be pulled downwards when needed, offering increased resistance at the end which requires it, and so causing the machine to right itself. The warping system of balancing has been mainly used on the monoplanes, and the ailerons on the biplanes; but latterly the tendency in aeroplane construction has been all in favour of aileron control, for the continual twisting and bending of the materials of the wings in warping is shown to have a bad effect upon them. In technical slang they tend to become ' tired ' and 'sloppy,' and in some cases permanently distorted. In the future, therefore, it looks as if warping will disappear and the use of ailerons entirely take its place; while in the perfected machines even now arriving in our midst, possessing ever more stability in the air, both warp and aileron will grow less and less necessary.

The battle-cry of the aeroplane designer of but a short while ago was 'Speed!' Later he altered it to 'Stability!' His aim and object was the production of the 'fool-proof' machine that shall fly itself in the air, not only without its pilot's guidance but actually in defiance of him by correcting his errors. Such a machine will rock to the winds and swing to the aerial waves even as a well-found boat; yet like the boat will never upset but return to an even keel. There are rival methods of achieving this end, some constructors (among them Orville Wright in America) seeking to attain it by 'automatic' and others by 'inherent' stability. The latter speak disrespectfully of the devices of the former; they call them 'gadget' stabilizers. The word is a trifle obscure, inasmuch as 'gadget' is the sea term for any miscellaneous article which does not appear to have a definite name, or at least one which comes ready at the moment. I asked a famous expert the other day to define a 'gadget stabilizer,' and he did so promptly and forcibly as 'any old thing which you hang on.' Less picturesquely an automatic stabilizer is some means of giving stability, such as a gyroscope or a pendulum, which is put on to a machine, and is not in itself an essential part of its construction.

The inherent stability people maintain that by careful design and construction alone, by theorist and practical man working side by side, by scientific disposal of weights and surfaces, different tendencies may be made to balance and correct each other, one set of oscillations to damp out another, and so the perfect machine be evolved. Further they have proved their point by succeeding. The naturally stable machine is no dream of to-morrow but the realization of to-day; not sprung upon us in a moment by some fresh epoch-making discovery, but now arrived at as the consummation of the labours which began with the earliest pioneers.

CHAPTER III

FLYING MACHINES OF TO-DAY

AND now as to the machines themselves.

It is obviously impossible, in a work of this size and modest pretension, to do more than glance at a few of them, and try to point out, in non-technical language, their chief characteristics. Nowadays when aviation and its terms are the everyday discussion of the multitude, and babbled of by the infant in the nursery, there is not the confusion that there used to be, and no one needs reminding, for example, that aeroplanes are divided into two great families—biplanes which lift with two main planes or supporting surfaces placed one above the other ; monoplanes which have but one (taking generally the form of two outstretched wings).

Nevertheless it is only yesterday that people were asking each other the difference between an aeroplane and a biplane, and only the day before yesterday that they were making an equal muddle over an aeroplane and an airship. When, but half a dozen years ago and less, a newspaper reporter shouted in head-lines of ' Record Flight of an Airship,' it was quite a toss up whether he meant a dirigible balloon or a heavier-than-air flying machine, and more than doubtful whether he knew himself.

But though the two great divisions of aeroplanes —biplanes and monoplanes—yet remain, they now must be yet further divided, and for our present purpose flying machines fall naturally enough into four classes—monoplanes, propeller biplanes, tractor biplanes, and hydro-aeroplanes.

Of course there are yet other machines which do not fit into any of these categories. There are triplanes, for example, and multiplanes, where the supporting surfaces are mounted in three or more tiers; there are hovering 'helicopters,' to be driven vertically upwards by propellers placed horizontally; 'ornithopters,' to flap their wings as birds; 'gyropters,' to revolve them; but since these are all in the experimental stage at present, and our space is severely limited, they need not here be considered.

As type of the monoplane we may select the ever famous Blériot, the first successful monoplane that ever flew, winner of innumerable triumphs, favoured mount of the world's greatest flyers. It is wonderful how little the modern Blériot has departed in design and construction from 'Blériot XI.' that flew to us across the Channel that never-to-be-forgotten July day of 1909; but it has to be remembered that the cross-Channel machine represented the result of nine whole years' labour on the part of its indefatigable inventor, who had finished his long and patient apprenticeship before ever his successors had begun upon their task.

To describe a Blériot monoplane—or any other aeroplane—we have to embark on that wonderful jargon of French and English terms that aviation has brought into use. The debt that the *Entente Cordiale* owed to the coming of flight can never be overestimated. It was on the flying-grounds of France and England that the two nations first learned thoroughly to understand and appreciate each other,

(*Flight*)

BLÉRIOT MONOPLANE

and one very definite result of their *rapprochement* there has been the addition of a score of new words to our English vocabulary which the best efforts of the man in the street, who has the greatest aversion to a foreign tongue, however little he minds mutilating his own, will never rid us of.

We say, therefore, that a Blériot machine is mounted on a 'chassis,' because the English 'under-carriage' is clumsy and less distinctive. The chassis carries the rubber-tyred wheels on which the machine runs and alights, and is constructed simply, but very strongly, of steel tubing. Upon it falls the brunt of bad landings, the shocks of running over rough ground; and even as a chain is no stronger than its weakest link, so upon the strength of the chassis the safety of pilot and machine entirely depends. The Blériot chassis is one of the safest and most ingenious landing gears ever devised. In it are included two stout rubber springs known as the 'shock absorbers.'

For the body of the machine we frequently use the word 'fuselage.' In the typical Blériot this is a wooden framework, covered in for the front portion, but simply bare spars behind, converging to the tail —by which homely word we now generally translate the French 'empennage.' This tail contains the elevator, attached as a hinged flap to the rear of a fixed horizontal plane, and a small upright movable plane which is the rudder. The two well-cambered wings with rounded tips which spread out on either side from the front of the body are hung from a framework of steel tubes on the top of the fuselage known as the 'cabane.' Beneath them, sunk in the fuselage, the pilot finds his seat, a cross-bar which operates the rudder at his feet, and in front of him a lever known as the 'cloche,' because the lower part of it is (or was, for latest machines are being made differently) shaped like the dome of a big electric bell. To this lever are attached the wires which move the elevator and warp the wings. In front of the pilot is the engine, and in front of all the big propeller, which, because it is placed in the front and draws the machine forward instead of driving it from behind, is not rightly a 'propeller' at all, but a 'tractor' screw.

The cross-Channel Blériot (*type Calais-Douvres*)

(*G. Bacon*)

BLÉRIOT MONOPLANE

Pilot's Seat

was a tiny little craft only 29 feet in span and 23 from nose to tail. Its famous rival, the Antoinette, now, alas! extinct, was a much larger bird, very beautiful and graceful, with square-tipped wings, cross tail and polished wood boat-shaped body tapering to a prow. The machine which most nearly resembles it nowadays is the fast English 'Martinsyde' monoplane, made by a firm long renowned for their skilled design and magnificent workmanship.

Until recently, when the swift tractor biplanes became a power in the land, the monoplane had it all its own way in the matter of speed, and the great racing machines have all been of monoplane type. Certainly the first time the Gordon-Bennett (the great international aerial race which is the 'blue ribbon' of the skies) was flown, it was won by a biplane—the American Curtiss. But that was at the very beginning of flight, when aeroplanes had barely emerged from the chrysalis stage, and the majority of them were caterpillars merely, so that 48 miles an hour was sufficient to transfix the crowd with amazement and bear off the prize. A year later Grahame-White won the race and secured the honour for this country by flying in a Blériot at 61 miles an hour. Next year America won it once more in the person of Weymann flying at 78 miles an hour in a Nieuport. The Nieuport was one of the first monoplanes to have an entirely covered-in bird-shaped fuselage. In their efforts to add to the speed by reducing the head resistance, constructors have aimed at attaining stream-line shape for the bodies of their craft, and as a result these resemble more and more Nature's practised flyers of several millions of years' experience. There is something uncannily bird-like in the Nieuport and other great racing monoplanes (such as the Morane-Saulnier, winner of 'Aerial Derbies' and other triumphs, or the Ponnier, successor to the well-known Hanriot), with their plump rounded bodies and well-developed ' crops ' ; and a good deal that is terrifying about their sightless heads and suggestion of blind, tremendous power.

Still in pursuit of speed, the French constructors next evolved the 'monocoque' body, where, instead of being an angular wooden framework covered with material, the fuselage is a perfectly smooth, hollow, torpedo-shaped tube elaborately built up of extremely

(*Flight*)

MORANE-SAULNIER

thin wood or metal, or even of a sort of papier mâché, around a core which is subsequently removed. With head resistance thus reduced to the last degree, and extremely powerful engines, Depurdussin monoplanes won the fourth and fifth Gordon-Bennett races (piloted by Vedrines and Prévost) at 105 and 124 miles an hour—the last well over 2 miles a minute ! The ' Dep ' machines have had wide popularity ; it was a sad blow for the French flying industry when in August 1913 M. Depurdussin was arrested for colossal frauds and his famous company went into liquidation.

At one time there was considerable discussion as to the safety of the monoplane, the belief being held, in some quarters, after an unlucky series of accidents, that it was a more dangerous craft than the biplane; and for a while monoplane flying was abandoned in the army. Careful investigation, however, failed to

(*The Aeroplane*)

DEPURDUSSIN

prove the point. The fact that a monoplane pilot cannot see so well, because the great wings on either side of him restrict his downward view, is now being got over by attaching the wings above the fuselage and leaving room for the aviator to look out underneath them. A monoplane made in this way is known as a 'parasol,' and during the War the plan has come into favour. The propeller in the front does not seriously interfere with the pilot's view, since, because of its rapid revolution, it is possible to look right through it, and its presence does not hide, but only slightly darkens, the prospect.

Turn we now to the biplanes, and in grateful acknowledgment let us glance first at the original American Wright machine—the first aeroplane that ever flew.

If we saw one of these quaint machines now—and he who can recall them is a perfect greybeard of aviation, though in point of years no hair of his head need have whitened—the first thing that would strike us is how low on the ground it sat. The Wright biplane was evolved straight away from a glider—was indeed but a glider fitted with an engine—and so, like a glider, it began its flying from aloft and not on the ground. Therefore it was not burdened with wheels on which to run along to gather speed, for indeed its feeble engine was incapable of raising it unaided from the earth; but in order to begin its flight, it was shot catapult-fashion down a long wooden rail by the force of a heavy weight let fall from the top of a little tower. This was ingenious but inconvenient, since it could scarcely carry its tower and rails about with it on a cross-country flight, and without them it was useless. Presently it was found that the tower could be dispensed with, and the rail, along which the machine ran to gather speed, alone was used, and formed a noteworthy feature at the first flying meetings. One of the earliest Wrights to be fitted with wheels was flown by Mr. Ogilvie at Lanark in 1910.

The early Wright was therefore a 'skid' machine mounted on skids or sledge-runners. There was a big double elevator in front, double rudder, but no tail, behind. It had two propellers at the back of the wings, driven by chains off a four-cylinder 24 horse-power engine that the Wrights designed and built themselves; and, as we know, it warped its wings. Though the Wright biplanes of the present day have wheels and a tail and have dropped the forward elevator, they are wonderfully similar to the early machines which first proved to the world that flight had arrived.

The American Wright biplane was the first machine to make flight practicable, but the French Henry Farman biplane was the first to make it popular. Most famous of the French biplanes, it has been the prototype of innumerable imitations and variations, and its advent in the early days of aviation was an epoch-making event. The old Henry Farman has been familiar to us since the first aviation meetings and the London to Manchester race. Looking at one of the original machines to-day, we see that the two main planes are of the same length, some 35 feet in span, and though well cambered, they differ from most other planes in being 'single surfaced' or covered with only one layer of material stretched over the top. The trailing edges of these planes are not continuous, but at each end a portion dangles downwards in a loose hinged flap. These are the 'ailerons'; in flight they are blown out level with the planes by the force of the wind, but, by means of controlling wires brought to a lever at the pilot's seat, they can be pulled down when needed. There are many wires about an early Farman machine. The

(*Flight*)

HENRY FARMAN BIPLANE

Old Style

bracing wires are divided into two sets: the 'flight' wires which hold the structure together in flight, and the 'rolling' wires which take the strain of running along the ground. The youthful aviator has to learn the difference between these wires, which, to his budding intelligence, may be reminiscent of a bird-cage.

The simple chassis contains two pairs of little rubber-tyred wheels, and between each pair, strapped to their axles by broad elastic bands, is a long curving sledge-runner or skid, suggestive of an alpine sportsman's 'ski,' on which the machine rests should the shock of a rough landing force the wheels upwards. An elevator plane, 15 feet span, is carried out well ahead of the main planes on long slender outriggers. Behind, four long spars or 'tail booms,' well braced together and gradually converging, carry a 'lifting' tail shaped like a square box without sides, at the rear of which project a pair of upright movable planes which are the rudder. The pilot's seat, which is not protected or built-in in any way, is right at the front ot the lower main plane, and behind the pilot's back is the engine and propeller (really a 'propeller' in this case).

This old Farman machine is the father of one huge family of aeroplanes now spoken of collectively and slightly contemptuously as 'box-kites.' At one time they had the field almost to themselves; now, at length, their day is passing. Never more will they win the great races as in the past, for, by modern standards, they are heavy, clumsy and slow. Nevertheless their sphere of usefulness is still vast, for they are the favourite school machines on which the great majority of would-be aviators learn to find their wings. Slow, not over-sensitive in steering, and affording the pilot a most admirable view in front for landing, they are excellent for teaching purposes. A too adventurous pupil finds his overweening ambition effectually curbed by the school box-kite, fitted with a low-powered engine. It is simply impossible for him to rise to great heights or to indulge in fancy 'stunts,' and he is fairly compelled to stick to sober flying until he has thoroughly mastered its A B C.

Practically every famous firm of biplane con-

(*The Aeroplane*)

HENRY FARMAN BIPLANE

New Style

structors have built box-kites in their time, founded on the Henry Farman design, and from them they have evolved all manner of successful variations. Very different from the originals are the aeroplanes which the Farman Brothers themselves now build, for Maurice Farman took up aeroplane construction very soon after his brother Henry, and produced a scarcely less famous machine; and though the two are now one firm, their biplanes are still quite separate and distinct. In the modern Henry Farman the front elevator has gone altogether, replaced by a flap in the tail. The pilot is no longer perched defenceless on the lower plane, exposed to every breeze that blows, but he sits right forward, ahead of his machine,

(*G. Bacon*)

MAURICE FARMAN SCHOOL MACHINE AT BUC

'The Mechanical Cow

sunk down in the 'nacelle'—a sort of covered-in prow, cosily sheltered by its walls and a wind-screen in front. There are extensions to the upper plane which make it much longer than the lower one, and the famous Farman skids are cut down very short or done away with altogether. In the old Maurice

Farman machine the skids are yet there, and are produced upwards to carry an elevator in front, working in conjunction with another elevator in the tail, so that they look, as we see them outlined against the sky, like the rockers of a safe nursery rocking-horse. The Maurice Farman has long been a most popular machine, known in the Service in affectionate derision as the ' mechanical cow ' (with a ' short-horn ' variety in which the front elevator is done away with). So safe and easy to fly is it, even in the worst weather, that it used to be said, with something like justice, that he who flew it was ' not an aviator but merely a Maurice Farman pilot.' At the end of 1913 the Farman Brothers could proudly boast that 1500 aviators had taken their certificate on Farman machines. By this time the number must be vastly larger. We may here note that the Voisin firm, who provided Henry Farman with his original ' mount ' before ever he produced his own first machine, now build a splendid military biplane that the French pilots claim as one of the best in the War.

The Farman machines are the most famous examples of the propeller, or in school language the ' pusher ' biplanes, where the engine and propeller are at the back of the main planes. More recently have appeared the ' tractor ' biplanes, where, even as in the monoplanes, the ' power unit ' is in the front and the aeroplane is drawn forwards in the air instead of being urged from behind. The relative merits and drawbacks of these two forms of craft, as upheld by their supporters, might be discussed to the end of the chapter. Undoubtedly the pilot and passenger of a 'pusher' have a better view ahead; and where guns are carried in aeroplanes it stands to reason they must be placed in the front and the engine behind, unless, indeed, the machines are to turn their tails and fight with stern-chasers.

On the other hand, in an accident the pilot of a tractor need not fear the engine crashing on the top of him, and for several reasons he is able to attain to greater speed and efficiency. For one thing, his tractor screw being right ahead of everything has fresh, undisturbed air to work in, instead of that which is all churned up by the front of the machine. For another point, as long as the propeller is at the back it has to be given room to revolve in, which means that the tail must be carried on wide, open framework, offering much head resistance; but with tractor in front the body of the machine may be made of stream-line form like a monoplane. The tractor biplanes, therefore, at first glance suggest a cross between biplane and monoplane, and have an air of strength, compactness and speed which their performances well bear out.

One of the very earliest of this type was the French Bréguet—a famous steel-built military machine that in its youthful days (and Bréguet its inventor was quite one of the pioneers of flight) was known as the Flying Coffee Pot. In England the earliest tractor biplane was, I believe, the design of A. V. Roe—one of the first three men to fly in this country—whose earliest machine of all, a triplane, was the first 'all British' aeroplane to get off the ground. From that day onwards Roe has patiently won his way from one success to another, constantly producing new inventions which have afterwards been adopted far and wide, and at this moment his 'Avroplanes' are some of the best flying machines in existence—swift and light, and, as we have seen, with a truly marvellous range of speed.

And the same may be said of the Sopwith and 'Bristol' tractor biplanes—children of the famous firms which have done more perhaps than any others to uphold the honour of the British manufacturer, against the world in general, and against their own countrymen, who liked to say that England lagged behind in aeroplane design, in particular.

Both in their larger machines constructed for one or more passengers beside the pilot, and in their small, immensely swift, single-seated 'Scouts,' they have studied military and naval requirements carefully and especially; as indeed have all aeroplane constructors, since it is as a machine for warfare that the aeroplane—at present at least—is in greatest demand.

Besides many aeroplanes bought from British and foreign manufacturers whose designs commended themselves to the authorities, the army possessed at the commencement of the War a large number of their own machines designed, though not all built, at the Royal Aircraft Factory at Farnborough. On these a vast amount of military

'BRISTOL' SCOUT

flying had already been done. The two most famous designs are those known as the 'B.E. 2,' and the more recent 'R.E. 1'; which last has aimed at, and secured, a very great measure of natural stability.

A machine which can fly at 90 miles an hour,

(*The Aeroplane*)

'B.E. 2'

and yet slow down to not much over 30, which can keep in the air for three hours without coming down for fuel, and can be trusted almost to look after itself while aloft, seems an ideal craft for military purposes; and there are quite a number of British tractor biplanes at the present time which fulfil all these conditions. In looking at some of the famous examples we may notice that the planes are 'staggered'—that is to say, the upper plane is mounted somewhat in advance of the lower one, the effect of which is to give the pilot a better view; since bringing forward the upper plane means bringing forward the pilot's seat as well. Also we may see that the chassis wheels are covered in, to lessen the head resistance and keep grass and soil out of the spokes—a small matter, but characteristic of the care bestowed on every detail.

Even to enumerate the famous aeroplanes of the present day would take too long; while to attempt to describe them in a little book of this size would be out of the question. The tens of thousands who weekly frequented the Hendon Aerodrome before the War are familiar with the splendid feats of the Grahame-White 'pusher' and tractor biplanes and huge five-seated 'char-à-bancs'; the light, swift, extremely efficient Caudrons (whose tractor biplanes differ from most others in having tail booms instead of a covered-in body); the naturally stable Handley Page, easy to recognize because of its backward-swept crescent-shaped wings—all most successful machines.

The habitués of Brooklands know the Vicars and many other celebrated craft (some already referred to), who have their home and flying-ground within 'the track.' At Eastchurch and elsewhere the naval pilots daily attest the merits of the Short biplanes. Yorkshiremen are proud of their Blackburn hailing from Leeds. Many of us have seen, and all of us have heard, of the Dunne 'inherent stability' machine, whose unusual backward-sloping wings and absence of tail relegate it to a class of its own. Lieutenant Dunne is a pioneer who has been experimenting ever since (and some time before) the early days of 1909, when rumours first began to get

(*G. Bacon*)

A 'SHORT BIPLANE

about of mysterious happenings in the Highlands, and of secret flying among the lonely moors of Blair-Atholl. Working on lines entirely different from anybody else, Dunne has been a long time in bringing his schemes to fruition ; but those who have seen —at Hendon and elsewhere—the pilot of his strange broad-arrow biplane leave the controls and wander out on to the wing while the machine flies steadily in air the while, will testify to the progress he has made towards the natural stability he aims at. The ring-shaped Cedric Lee, known in pleasant aviation parlance as the 'dough-nut,' is another example of an attempt to win inherent stability by 'weird wings.'

Alas! that we are never more to see—save at the South Kensington Museum where it is now removed—Cody's 'Flying Cathedral'—the mighty biplane, most original in its design, reflecting its author's vigorous personality in all manner of 'Codyesque' touches, which to the British public was once the most popular aerial craft in existence from the point of view of the multitude. The excellence of the great machine was proved on numberless occasions, notably when it won the Michelin prizes, completed the Circuit of Britain, and beat the whole world in open competition at the Military Trials on Salisbury Plain in 1912. Alas! Cody and his biplane have gone together, since the two could not be severed. It needed a Cody to pilot a 'Cody Flyer.'

Late in the day to enter the field, but soon forging rapidly to the very forefront by force of brains and enterprise, Germany prepared for the Great War the mightiest fleet of flying machines ever seen. Experts have estimated the number at 1300, of which more than half were the renowned 'Taubes'—monoplanes whose rounded wings with turned-up tips suggest the doves or pigeons they take their

(*The Aeroplane*)

(*The Aeroplane*)

GERMAN 'D.F.W.' BIPLANES

names from. Built all of steel, painted blue to fade into the sky, they owe their origin to the famous Austrian constructor Etrich, who was helped to his design by study of the Zanonia leaf, one of Nature's own gliders. The speed of a Taube is 60 miles an hour, but war experience demands a faster, and more especially, a faster climbing craft, and latterly tractor biplanes, 'Aviatik,' 'Albatros,' 'D.F.W.,' and others have proved superior. German aeroplanes are big and heavy, but singularly efficient and well-engined. Built for the most part with backward sloping 'arrow form' planes of the Dunne and Handley Page type, they aim particularly at stability; while the German engines—the famous Mercèdés in particular—are unsurpassed. It has been well for us that the German temperament does not conduce, apparently, to the production of pilots of a quality to match their aeroplanes and engine-power.

The problem of the hydro-aeroplane, the flying machine which shall rise from and alight on the surface of the water, engaged the attention of certain minds at a very early stage in the history of flight; indeed some of the first pioneers, such as Langley in America and Blériot and Voisin in France, made experiments over and on (and frequently 'in') water with their craft before ever they succeeded in getting them off the land. The advantages of having a big lake, or the sea itself, for a flying 'ground' (pardon the word) are manifest. The naval possibilities for sea-planes are enormous. The matter is all-important as well as specially fascinating, and recently it has assumed ever larger proportions and absorbed more and more of the best brains in the world of aviation.

And it is by no means an easy task. Merely to fit floats instead of wheels to an ordinary aeroplane does not convert it into a practicable hydro-aeroplane (popularly known as a 'water-plane' or a 'sea-plane'), nor does it enable it to rise off the water. To run a flying machine on wheels along smooth ground sufficiently quickly to make it lift, takes, as we know, more power than to keep it flying in the air. When it comes to forcing heavily laden, awkward-shaped floats, at great speed, through a more or less yielding fluid such as water, so much increasing resistance may be set up as may effectually keep the machine from ever lifting at all.

Then again the presence of big, heavy floats, slung below the planes, instead of a light compact chassis, alters the whole question of the balance of the machine, puts the centre of gravity in another place, and tends to set up a sort of pendulum effect which it has ever been the object of the aviator to avoid. Construction, design, distribution of weights and surfaces, must all be reconsidered by the aeroplane builder who wishes to give his bird webbed feet.

And when it is a sea-bird he desires to evolve the matter becomes yet more difficult. Enormous strength must be given to withstand the buffeting of the waves. Increased strength means increased weight, which in turn means bigger floats, and bigger floats spell greater resistance. Contrary to general opinion, water can be extremely hard—hard as concrete or granite to land upon—and except in sheltered harbours or land-locked bays a descent on sea is much rougher than on land. As one aviator complained, 'water is so soft at low speeds, and so exceedingly hard at high!' Then again the launching of craft on the uneasy waves may be, in itself, a tremendous business. Altogether the problem is a vast one, and, perhaps for this very reason, has a fascination all its own.

One great point is the devising of a float which shall readily leave the water. A well-designed float will tend, as the speed increases, to lift of itself and skim over the surface instead of ploughing heavily through the waves. Some forty years ago and more a Sussex clergyman of the name of Ramus conceived and laid before the Admiralty a marvellous invention, whereby the speed of a battleship might be vastly increased by making the hull of two wedge-shaped bodies, one abaft the other, which should tend to lift it out of the water when travelling at high speed. The whole plan (which included rockets in its scheme) was impracticable, but it contained the germ of what is known as the 'hydroplane'—an object, boat or float, of such a shape that, when propelled rapidly along, wedges itself out of the water and skims lightly along the top. Hydroplane racing motor-boats have been in existence for some while, and hydroplane floats are fitted to many water-planes.

(It will be seen from the foregoing that those who call a hydro-aeroplane a 'hydroplane' err in so doing.)

One of the peculiarities of the hydroplane float is that it is 'stepped'—that is to say, the lower surface, instead of being all of one piece, changes or 'steps' abruptly to another level. Some floats have one step, some more. Their main object is to help the float to become 'unstuck.' There is a great tendency for water to hold on to an object lying flat upon it. Lay the palm of your hand flat on the water and feel the resistance offered when you lift it straight upwards. The step allows the air to come in underneath the under surface of the float, and so does away with this suction effect; and the float 'unsticks' (the French verb is *decoller*) readily. Many experts, however, declare that the same effect can be got without the awkward steps (which add to the trouble of construction), and so these have, in many cases, been abandoned.

Glenn Curtiss, the American aviator whose fame is only second to that of the Wrights, was the first to experiment with water-planes; and he did so in all sorts of ways, both with machines to lift directly off the water and those which should rise off platforms built on the decks of ships. In this country the first work was done in the Lake District by Oscar Gnosspelius and Edward Wakefield, their scene of action the glassy surface of Windermere—surely the most picturesque flying-ground in all the world. Here to begin with they tested their hydroplane floats by dragging them through the water at the back of a motor launch, and when they had arrived at the best form they fitted them to specially designed aeroplanes with extremely successful results. Visitors to Lakeland are familiar with the white-winged water-birds whose home is among the mountains, and some, like the writer, may have been privileged to explore the lovely Windermere shores from above, by their aid. A wonderful power belongs to the flyer at a certain height over lake or sea—that of being able to see down beneath the surface of the water, even when it is rough with breaking waves. In days before the coming of the aeroplane my father succeeded not only in seeing, but also in photographing, the sand shoals at the bottom of the Irish Sea, from a balloon, and the bottom of the lake is clearly visible in a photograph I took from the waterplane over Bowness.

While the work at Windermere was only beginning, just a few miles away, at Barrow, a naval officer, then Commander Schwann (assisted later by S. V. Sippe), stationed there in connection with the building of an ill-fated air-ship, whiled away the time of weary waiting by endeavouring to make a water-plane rise off the docks; the result of the modest experiments (carried out at Commander Schwann's own expense) proving far more valuable and infinitely less dearly bought, than those afforded by the giant failure of a dirigible which cost the tax-payer so many thousands of pounds. A. V. Roe constructed machines for both the Windermere and

Windermere from a Water-plane

(*G. Bacon*)

THE FERRY HOTEL

(*G. Bacon*)

BOWNESS

(Showing bottom of lake on left of picture)

Barrow ventures, and learned much knowledge thereby which he has since turned to good account in his famous water-planes of the present day.

Equally early in the field were the Shorts at Eastchurch, experimenting for the navy. In proof of the success of their work, Frank McClean, enthusiastic sportsman, who has ever been such a munificent and patriotic supporter of British aviation in general and the splendid work done in Sheppey in particular, flew a Short hydrobiplane in August 1912 right up the Thames, from Eastchurch to Westminster, under the bridges of London, proving visually to the heedless city, chattering idly of foreign progress, what its own countrymen could do. Eighteen months later he took a Short sea-plane right up the Nile as far as Khartoum. The naval sea-planes turned out by the Shorts—oldest established firm of aeroplane constructors in England—are second to none in all the world. As needs must be for sea work, they are large and very strongly constructed, fitted with 'wireless,' weighing, fully loaded with pilot, passenger and fuel, a ton and a half; with wings of 60-foot span, which, for travelling purposes, fold back along the body, and huge floats divided into water-tight compartments. Yet recent machines can travel at 78 miles an hour and climb 3000 feet in eight minutes—surely the last word in efficiency.

Mention has already been made of the extremely successful 'Wight' sea-plane constructed at Cowes by the great shipbuilding firm of J. Samuel White and Co., to the designs of that clever man Howard Wright

THE 'WIGHT' SEA-PLANE OVER COWES

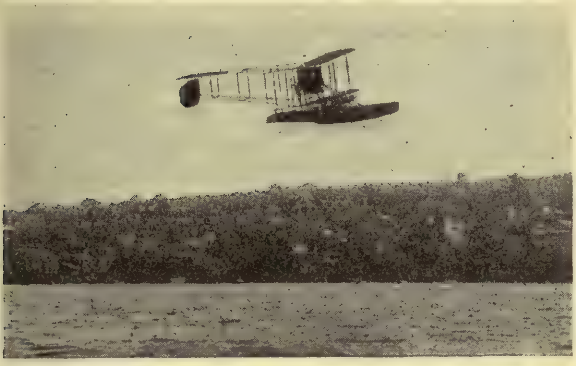
The writer will not readily forget a flight she was privileged to make over the waters of the Solent in one of these machines a few weeks before the breaking out of the War. The great propeller hydro-biplane rose off the surface of the water after a run of only 40 yards, forcing her way through the top of the waves with a shallow, clean-cut furrow, and but the thinnest cloud of white spray playing about her three-stepped hydroplane floats. The engine, a 200 horse-power Salmson (a Gnome is not well suited for sea-planes since the salt water rusts its polished steel), could be started from the pilot's seat by a self-starting arrangement worked by compressed air on the principle of a soda-water siphon. It is very evident that a means of starting the engine from within must form part of the equipment of every water-plane, since if the engine stops, with the machine out upon the water, it is clearly impossible to expect the pilot to jump out, run round and swing the propeller as he might on dry land.

Landing on water offers a special difficulty to pilots, inasmuch as water being transparent, it is often very hard indeed to estimate the height above its surface. Again and again have machines been smashed up through an aviator thinking himself nearer or farther from the waves than he really was ; but in the case of the 'Wight' machine this trouble need never arise. So well designed is it that the pilot has merely to throttle down his engine until he is travelling at 36 miles an hour, the minimum speed, and then simply to await results, confident that he will settle down gently and without shock from whatever height he descends. This happy fact of course renders night flying over the sea not only possible but safe. Sea flying has this great advantage at least, that there is unlimited space to land on.

In all the half-hour that we were up, circling, turning and banking, my pilot—Gordon England—did not once have occasion to touch the ailerons. Ailerons indeed seem growing obsolete, if only because at the high speeds now reached there simply is not time for them to take effect. We travelled, for the most part, at 80 miles an hour; but with the propeller behind and a wind-screen in front the draught was not even inconvenient. Very different had been my experience flying at 70 miles an hour in a 'Dep' hydro-monoplane at Windermere, where the 'slip-stream' of the tractor, just behind which I sat, had seemed to blow the breath from my nostrils and the eyes out of my head.

Great luck was mine at Cowes that day, for presently there swept overhead, from the naval station at Calshot, a Sopwith 'bat-boat' flying strong and steady. The Sopwith Company supply yet another splendid example of an English firm which can compete with the whole world. In proof of this a Sopwith single-seater tractor hydro-biplane, 100 horse-power Gnome engine, flying at over 90 miles an hour, piloted by Howard Pixton, carried off the Schneider Cup at Monaco in April 1914—the first British machine to win a big international race. The Sopwith 'bat-boat' (the word is derived from

Sopwith Sea-planes



THE 'BAT-BOAT

100 H.P. TRACTOR SEA-PLANE

Kipling's immortal story *With the Night Mail*) is a most successful example of a water-plane where the place of the floats is taken by an actual boat in which the aviator sits. Curtiss has evolved several flying boats of this description, one of which, it is hoped, will make the Atlantic crossing. Practically all the great continental aeroplane firms have turned their attention recently to hydro-aeroplanes. Let us hope that England may long hold the lead she has undoubtedly won.

And now just a few last words, in an overlong chapter, concerning the actual manufacture of the aerial craft we have been discussing. Even before the War this was going on in many places: at Short's factory in the Isle of Sheppey, with a newly opened sea-plane branch in the Medway; at the busy Sopwith works at Kingston-on-Thames, the Avro works in Manchester, Vicars at Erith, Grahame-White's and others at Hendon; at Brooklands, where is a large factory of British-made Blériots, as well as the Martinsyde and other shops; at Farnborough, Cowes, and elsewhere.

Chief among those of 'the trade' who have reaped the benefit of foresight and enterprise, must certainly be counted Sir George White, of Bristol electric-car fame. Right back at the very commencement of aviation, when the idea that flight had any commercial possibilities about it was openly scouted, he read aright the signs of the times, and founded, in May 1910, the British and Colonial Aeroplane Company works at Filton, on the outskirts of Bristol,

BUILDING AEROPLANES AT THE BRISTOL WORKS which in peace time employs three or four hundred men, and is capable of turning out an aeroplane a day. Here are built aeroplanes for the governments of many foreign nations, and large numbers of 'B.E. 2's' and other craft for the War Office and Admiralty. (The wicker-work pilots' seats for the military machines, by the way, are specially manufactured by the blind at the Bristol Blind School.) Within the huge sheds we may watch the whole process of the building of an aeroplane, from the stacks of rough planks to the completed machine. The question of wood is becoming a very serious one. Ash is the favourite for spars and framework, as being light and tough and springy. But it must be English ash, slowly grown, long and straight, and not too old. Ash trees take long in growing, the demand is great and ever increasing; the supply grows rapidly less and prices rise in proportion. Already spruce from Russia is being used in larger and larger quantities wherever possible, and the dearth of suitable wood will hasten the arrival of all-steel machines.

Carpenters' shops, metal-workers' shops, and all the costly and elaborate machinery they entail, forges, drawing offices, laboratories, have their part in the busy factory; not to mention the rooms where the closely woven cotton fabric, costing 2s. 2d. a yard and more, is stretched upon the wings, and then plentifully 'doped' with special preparation, which makes it weatherproof, smooth and taut. There is apparatus for the careful testing of the propellers, rooms where the engines are put through their paces. Finally the whole machine is 'assembled' preparatory to being packed up and dispatched to the flying-ground, where first it spreads its spotless wings for flight.

CHAPTER IV

THE POWER UNIT

IT is inevitable that a book which professes to be 'All about Flying' should make some attempt, however brief and sketchy, to trace the outlines of what is sometimes known as the 'Power Unit' of the aeroplane—that is to say, the engine and propeller and all the apparatus that appertains to their proper working.

An aeroplane is as dependent upon its power unit as a motor-car upon its motor, or a railway train upon its locomotive. Of late years aeroplane design and aeroplane engines have developed side by side, each advance in the one making progress in the other possible and inevitable. In the beginning, as we have seen, it was the lack of a suitable engine alone that held back aviation from expectant generations.

The problem was to arrive at an engine sufficiently light in comparison to its horse-power. When in 1809 Cayley first conceived the idea of flying with an engine-driven machine he found that the steam-engine of his day, including fuel for an hour, would weigh 163 lbs. for a single horse-power. Fifty years later a French engineer, Giffard by name, attempted to turn a balloon into an airship by putting an engine into it; and the very lightest thing he could procure for his purpose was a 3 horse-power steam-engine weighing without its fuel a good 4 cwt. In the early nineties, when Maxim was making experiments with almost the first flying machine that ever lifted itself from the ground, he evolved a steam-engine which was considered a very miracle of lightness because it only weighed about 20 lbs. to every horse-power developed. 'It is good, but it is not good enough,' I remember hearing Maxim say. 'What we want is a machine that shall yield a horse-power for the weight of a barn-door hen.'

It has come (the high-power Gnome motors develop a horse-power for only *two pounds* weight!)—but it is not a steam-engine. This form of engine is ruled out of the race for lightness because it must always be provided with a boiler. A steam-engine consists mainly of a hollow cylinder closed at each end, inside which a piston—a thick disc fitting closely to the inside walls—is made to travel up and down. The force which compels it to do so is the pressure of expanding steam, which is generated in a boiler and admitted under pressure through a valve at one end of the cylinder. The pressure of the expanding steam drives the piston down to the other end of the cylinder, where it meets another supply of 'live' steam, fresh from the boiler, admitted through another valve, which sends it back again. Up and down the piston travels ceaselessly, and by means of a connecting-rod is made to revolve a shaft; and so its to and fro motion is converted into rotary motion, which can be used to make wheels or paddles or propellers revolve. To insure that the one motion is turned smoothly into the other, so that the shaft revolves perfectly evenly all the time, it is provided with a heavy fly-wheel which, once set moving, has so much momentum of its own that it carries the shaft along, although there are times when it has a momentary tendency to stop.

This is substantially the form of engine which James Watt evolved more than a century ago when (according to legend) he watched the steam raising the lid of his mother's kettle, and realized that in that steam lay a mighty force that might be harnessed to the labours of the world. Ever since his day the steam-engine has been improved and rendered more and more efficient; but it is obvious that an apparatus where water has to be converted into steam in a boiler, heated by a furnace, can never be made a specially light one, and hence it came about that progress in flight was at a standstill until man lit upon a substitute to drive his pistons to and fro. And presently he found it in the expansive force of an explosion of gas and air. When paterfamilias wakes in the night, and his nose tells him that the new servant maid, raw from the country, has blown out the gas in the kitchen instead of turning it off, he knows better than to go down with a lighted candle to remedy the mischief. He is aware that a mixture of gas and air forms a highly inflammable compound, an explosion of which may be sufficient to blow out the windows and wreck the house. Half a century ago it occurred to ingenious man that this explosive force, which had often worked him woe, might also be harnessed to his needs; and he invented the gas-engine, in which a series of small and properly regulated explosions are used, in the place of steam, to work a piston up and down a cylinder.

But yet more recently engineers, searching for efficient and convenient light engines to drive the motor-cars which were becoming the toys of the wealthy, hit upon the idea of making their explosive compound not of air and household gas, but of air and vapour of that highly volatile substance which we call petrol, and which is distilled from the mineral oil petroleum. In the petrol-driven, internal-combustion engine the volatile petrol is made to turn into vapour and mixed with air in the 'carburettor,' an outer chamber which leads into the cylinder. The mixture is drawn into the cylinder by a down stroke of the piston and there compressed by the piston moving back upon it. After this an electric spark ignites or fires it, and the force of the explosion drives the piston forward again. The compression of the mixture of vapour and air, before it is fired by the electric spark, is necessary to render the explosion powerful and efficient. Should it ignite before it has been fully compressed the result is a 'back-fire,' noisy but useless. On the return stroke after the explosion the piston forces out the burnt gases that remain, known as the 'exhaust,' through the exhaust valve. It is the forcing of them out through this valve that causes the familiar noise of the petrol-engine. In a motor-car the noise is deadened by a ' silencer ' ; but an aeroplane before the War was generally allowed to fly with ' open exhaust,' making as much sound as it would.

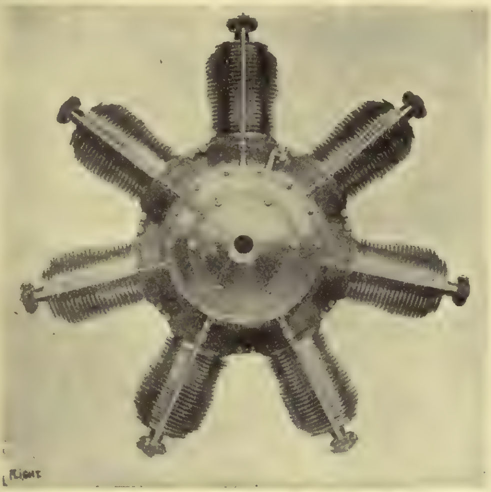
The engine which we have been describing works upon what is known as the ' four-cycle ' system—that is, the piston makes four complete strokes for every working or ' power ' stroke. In the ordinary form of steam-engine, where the piston is forced backwards and forwards by the steam pressing upon it at each end of the cylinder in turn, every stroke is a power stroke. But, as we have seen, in the petrol-engine the piston is given a power stroke only when the explosion forces it to one end of the cylinder, and the impetus it thus obtains has to tide over three more strokes—the ' exhaust ' which forces out the spent gases, the ' induction ' which sucks in the new, and the ' compression ' which compresses them before the explosion gives the next power stroke. The work is therefore done—if I may be allowed so to express it—in jerks, or at least would be if suitable means were not taken to prevent it. The heavy fly-wheel, which has the property of absorbing surplus energy at a time when it is not needed and yielding it up again when it is wanted, is one of these means, and in addition the majority of motor-car engines, and all aeroplane engines, have a number of cylinders each doing its power stroke at a different moment, and so, in this way, the jerks are less violent and follow each other more frequently.

The aeroplane engine, although it resembles and was evolved from the motor-car engine, is not the same. From the very beginning it was discovered that the peculiar conditions of flight demanded a special type of motor, and the Wrights and other pioneers had to construct their own variations. In addition to having to be specially light the aero engine must also be peculiarly efficient; for all the while it is driving the aeroplane through the air it is, as it were, climbing a perpetual hill. Nowadays when planes are better designed, and there is more lift about them, and greater variation in the angles at which they fly, the engine, as we have already seen, can be throttled down and not urged all the while to its greatest efforts; but in the early days when there was no 'margin,' and the machines could only just manage to get into the air and keep there, the motor must be working 'all out' all the while, and doing so without any personal attention, for the aviator had his hands (and feet!) too fully occupied with the steering and balancing of his craft to attend to anything else.

One great difficulty to contend with in the petrol-engine is the keeping of the cylinders sufficiently cool. The constant explosions raise the gases to a high temperature, and the interior of the cylinder would soon get extremely hot if means were not taken to prevent it. Overheating renders efficient lubrication impossible, and damage to the cylinder walls would quickly result, to say nothing of the trouble which would arise from the premature explosion of the mixture—or 'back-firing.' Petrol-engines are therefore carefully and elaborately cooled, either by air or water. With water-cooling, water is kept constantly circulating through a space known as a 'jacket,' outside the cylinders; and so that it can be used over and over again, the water is itself cooled by being continually passed through a radiator—an arrangement of tiny tubes about which the air can freely blow. In air-cooled engines the contact of the air upon the outside of the cylinders is relied upon to cool them, and so it is obvious that air-cooling can best be employed when the cylinders pass very rapidly through the air.

This is the case with the Gnome rotary motor—the famous aeroplane engine which has played so great a part in the progress of aviation. It was in the summer of 1909 that the Gnome came into fashion, and its advent was almost sensational. In the middle of the great Rheims meeting Farman fitted one into his biplane, and four hours afterwards went out and beat the world's records for length and time of flight and won £2000 by so doing. 'Have you seen the wonderful new engine?' was the question in everybody's mouth. 'A Gnome would make even a tea-tray fly!'

The Gnome motor in its original and commonest form has seven cylinders arranged like the spokes of a wheel or the rays of a conventional star; and it has this great peculiarity, that whereas in the vast majority of other engines the cylinders are stationary and the main shaft revolves, in the Gnome it is the main shaft which is stationary while the cylinders are compelled to revolve around it. There are two special advantages about this unusual proceeding. For one thing the revolving cylinders form their own fly-wheel; for another, their rapid progress through the air is sufficient to keep them cool without any further



(*Flight*)

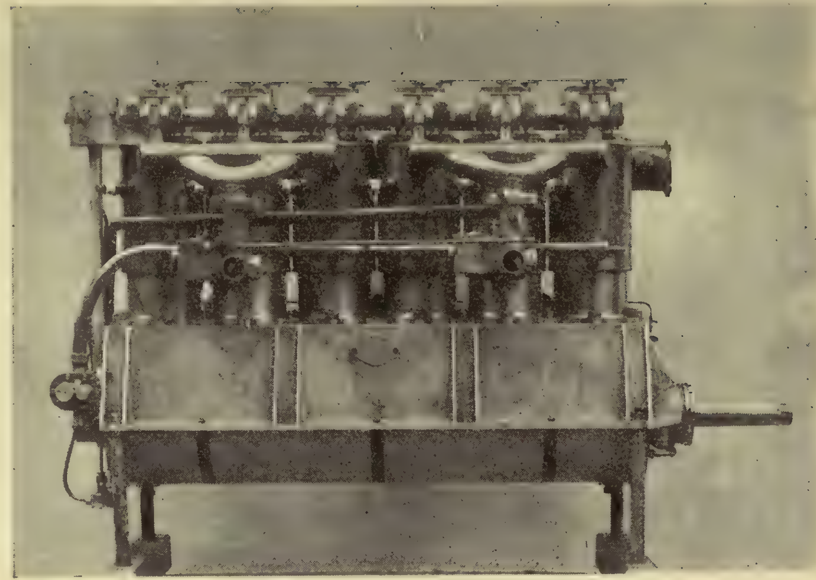
MONOSOUPAPE GNOME ENGINE (80 H.P.)

apparatus. To aid them in their cooling, the polished steel cylinders are made with a number of ribs or fins on the outside, which facilitate the circulation of the air around them.

Of course there are corresponding disadvantages. One is the lubrication which, with all high-speed motors, is a serious matter. With a Gnome only the purest castor-oil can be employed, and it is used most lavishly because of its cooling effect—practically a gallon of oil to every three gallons of petrol. Those who fly behind a Gnome can testify to how freely and light-heartedly it flings its lubricant around; while the smell of burnt castor-oil belongs as essentially to a flying-ground as the scent of clover to June meadows.

At one time it was held that the gyroscopic effect of the rotary motor must have important influence upon the steering of the aeroplane; but experience seems to prove that—to use the expressive colloquialism—'there 's not much in it.' Of more far-reaching importance is the fact that the Gnome cannot be throttled down to the same extent as many other aero engines. It *has* to run 'all out'; and the only way in which the speed can be greatly varied is by cutting off the motor and switching it on again, which of course gives the aviator more to do. The latest and lightest variation of the Gnome is the 'monosoupape,' differing chiefly in a matter of valves.

Among famous aeroplane engines of the present day the Clerget and Le Rhône are other examples of the rotary type, where the cylinders are arranged 'radially' (star fashion) and all revolve. In other motors although the cylinders are stationary they may still, for the sake of lightness, be radial (the Anzani is a case in point); or they may be arranged in pairs, each pair forming the letter V. A popular example of the 'V type' engine is the Renault,



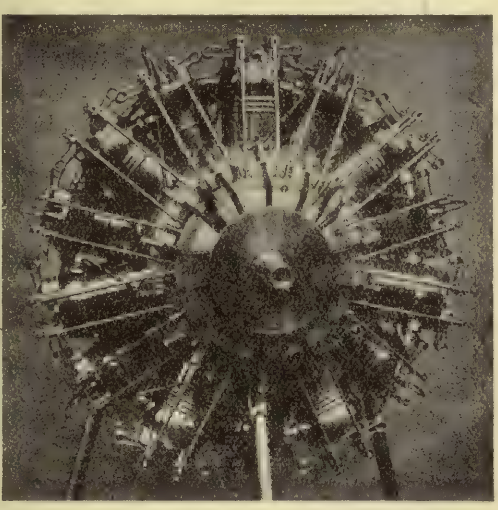
GREEN ENGINE (120 H.P.)

largely used on military machines. The Renault, by the way, is air-cooled by means of a fan revolving in front of the engine which drives air past the cylinders. Probably the best known of the English motors is the Green, of the stationary 'vertical' type, where the four or six cylinders are upright and ranged in line. The Green engines vary, according to size, from 30 to 120 horse-power; and among their famous feats Hawker's water-plane flight round Great Britain has been the most popular. The great naval sea-planes of the present day demand very powerful engines. Very largely and successfully used for this purpose is the great 'Salmson'—200 horse-power—a most impressive-looking piece of work with its fourteen cylinders, fixed but arranged radially, covered with bright copper water-jackets.

It is clearly impossible here even to name the famous engines—British and foreign—of the day. But the Power Unit of an aeroplane does not consist of the engine alone, and it would be small use to labour to improve the motor if its horse-power were to be squandered by an inefficient propeller; and the task of the propeller designer is a complex and difficult one—not yet even fully understood.

His problem is to produce an aerial screw which shall force its way through the air with the greatest amount of 'thrust' to the least amount of air resistance—the 'thrust' of a propeller being the force with which it drives the air backwards or urges the aeroplane forwards.

And to obtain this he must shape his blades in particular fashion. The principle of the propeller is, as we know, the principle of the screw; but the shape of a screw has always to be modified to suit the medium it is working in. The screw propeller of a ship is not of the same form as the screw which bores



'SALMSON' ENGINE (200 H.P.)

through wood; and equally a ship's propeller would be no good to drive a flying machine.

For one thing, the 'pitch' has to be entirely different. The pitch of a screw is the distance it would travel forward in one complete turn supposing it were screwing into something solid, such as wood. But if it were screwing into soft soap, let us say, it would not go so far for a single turn, for the soap would yield to it, and it would push the soap back while it was pushing itself forward. The amount which the soap was pushed backwards would be called the 'slip.' In other words the 'slip' of a screw is the difference between the distance the screw should theoretically travel and its actual progress.

It follows that with a propeller screwing its way into such a tremendously yielding fluid as air, there must be a great amount of slip. We are made conscious of this fact in a tractor aeroplane when we sit behind the propeller and its draught blows over us. The technical name for this draught is the 'slip-stream.'

The designer of an aerial propeller has to form his blades so that they may lay hold of as much air as possible in a given time. He has to work out, in fact, in his own way, the 'lift and drift' problem of the aeroplane constructor; and he finds that the same laws hold true for planes and blades. He discovers that a long narrow blade is more efficient than a short broad one; that the blade exercises more thrust if it is curved; and that, even as in the fixed planes, the greater the speed the smaller the angle of inclination. The tip of a propeller blade travels much faster in space than a point nearer the axis or boss; consequently if the pitch of the blade from axis to tip were uniform the air would be driven backwards with a greater velocity at the tip than at the axis. If, however, there is a suitable variation of the pitch along the blade, the air can be driven backwards at the same velocity at every point. A propeller blade, therefore, starts thick at the axis and fines away to paper-knife edge at the tip. Other things being equal, a large propeller turning comparatively slowly gives more thrust than a small one driven at high speed; but a small propeller has the advantage that it can be built stronger for its weight. To be equally strong a large propeller must be made disproportionately heavy.

Travelling as it does at tremendous speed—its tips moving at hundreds of miles an hour—a propeller has to be very specially constructed. Formerly many propellers were made of metal; until presently it was found that metal had a tendency to become 'tired' and break in the air; and a broken, jagged propeller blade flying at the speed of a projectile is an ugly customer to deal with. With wood there is not this risk. The wooden propeller is not made all of one piece but is 'laminated'—that is to say, built up of a number of layers, six or eight probably—generally of French walnut, most carefully selected and fixed together, not lying parallel but sort of fan fashion, so that the grain is best arranged to stand the strain set up by the rapid revolution. The whole is highly polished so as to render it as 'slippery' as possible in its passage through the air; and it is, moreover, covered with a varnish that will withstand water, and hot castor-oil. Propellers are generally two-bladed, but four blades are not infrequently employed.

A propeller is a delicate and costly thing, liable to all sorts of accidents, some of an unlooked-for character. Lady passengers are warned to see that they have no loose portions to their dress when they go flying. A woollen cap blown into the propeller can chip its edge, a pin be firmly embedded in it. Propellers of sea-planes have their tips sheathed in metal to prevent their being splintered by waves splashing upon them ; and even the rain-drops of a heavy shower have been known to fray the leading edge until it looked as if it had been gnawn by rats.

In general the propeller acts as the fly-wheel of the aero engine, levelling up the ' jerks ' as we have already described. Being made of wood, however, it is liable to have a certain amount of ' spring ' about it, and a vibration can be set up in it known as ' propeller flutter,' which may seriously lower the efficiency. We are speaking now, of course, of the non-rotary engine. In the Gnome the revolving cylinders form a much more effective fly-wheel, and the consequent absence of flutter is one great reason for the success of this form of motor.

CHAPTER V

HEROES OF FLIGHT

SO far, in our opening chapter, we have traced the history of aviation down to the first long flight of the Wright Brothers in 1905. Only a decade ago, and yet these were the prehistoric days of the great invention. Ten years ago we said of the impossible, 'You might as well ask me to fly!'

The prophets of this world are a race of men who will never learn wisdom. Doctor Johnson declared that man would never be able to travel at 20 miles an hour because he would not be able to breathe and withstand the tremendous air resistance. (Had the old—hm—philosopher never encountered a 20-mile wind!) Eighty years ago doctors were declaring that 'the air of damp tunnels, the deafening peals, the clanking chains and dismal glare' of railway travel would undermine the strongest constitution. Sportsmen wrote that the 'poisonous breath' of the engines would kill all the game, farmers that it would ruin the fleeces of the sheep; while the authorities of Eton College raised dignified protest against the coming of the G.W.R. because they said it would be perfectly impossible to keep the Eton boys off the rails. How did we greet the first cyclist? What did we say when motor-cars arrived? We would rather not recollect. Even so let us draw a merciful veil over what we were chattering and writing about flight only half ten years ago.

The Wrights having completed a machine that could stay half an hour in the air, packed it away and set off to bargain with the various governments for the sale of their invention. They were silent, reserved men, and they wished to keep their secret. Only vague rumours of their success filtered through to Europe, and even these were not believed in. Experience had proved that tales of wonder hailing from America must be accepted *cum grano salis*

Meanwhile experiments were being made in France by Captain Ferber, by the Brothers Voisin, by Esnault Pelterie, by an enthusiast called Louis Blériot. Presently Santos Dumont, burning for fresh worlds to conquer, entered into the sport. A double honour was his. He who was the pioneer of the airship was soon hailed as the pioneer of the flying machine also. For in October 1906, in a weird 'canard' ('Duck' or 'tail first') machine, resembling several big box-kites put together, with a 50 horse-power motor, he achieved a mighty hop of 80 yards. Soon he doubled and then trebled this distance. The official observers were so overcome with emotion that they forgot to observe, the public nearly wrecked his machine in their enthusiasm, and Paris waxed delirious. Then the Voisin Brothers constructed a better designed machine and arranged with Henry Farman, an Anglo-French racing motorist, to fly it. In January 1908 he flew the first circular mile, winning a large prize offered years before for the then impossible feat. Shortly after Delagrange managed to stay in the air for nine minutes. Proudly the French nation boasted that flying was now an accomplished fact, and to France belonged the honour of its invention.

Then at last those mysterious Brothers Wright, their machine packed away these two years, their quest of a purchaser unsuccessful, were forced into the open. 'We have flown,' they said, 'three years before you did; we have flown many times further. If you want proof behold us now.' Orville Wright took one machine to demonstrate with in America, Wilbur brought another to France. Still incredulous, the French flyers crowded to see him. They marvelled at his strange machine, they sneered at its home-made appearance, but when it rose in air they sneered no more. 'Ah well!' sighed Delagrange, 'we are beaten! We don't exist!'

No more they did for the next few months. The Wrights held the entire field and the French flyers were practically forgotten until suddenly and dramatically they came into their own again.

In the summer of 1909 a young sportsman of mixed nationality, Hubert Latham by name, announced that he was about to make an attempt to win the £1000 prize offered by the *Daily Mail* for the first flight across the Channel. The world was frankly incredulous, for Latham was practically unknown, and so was his machine. Certainly it was built by a famous French firm, the 'Antoinette' Company, makers of a well-known light petrol motor, but then it was a monoplane, and everybody knew that a Wright biplane was the only aeroplane that could really fly.

Therefore the crowds that blackened the Dover cliffs, day after day of a tempestuous July, were unbelieving; and grew more so as one storm succeeded another, and beyond one abortive attempt when Latham dropped in the sea after travelling only 8 miles, nothing whatever happened. The disgusted newspaper reporters returned to London, the spectators melted away, and thus it happened that at five o'clock on a Sunday morning, in the brief calm between two gales, a stolid Kentish policeman was the only Englishman to see a big white bird fly in from the sea, and swoop down from heaven on the grass beside him. But the man with a lame foot and hawk nose who limped out of it and shook him excitedly by the hand, was not Latham, and his tiny workmanlike craft was not the large, graceful Antoinette. The British public opened its daily paper on the Monday morning to find that the Channel was flown indeed, but the hero of the flight was Louis Blériot. Before twenty-four hours had elapsed the fame of the Wright Brothers was eclipsed and the Frenchmen had come back into their own.

With the first crossing of the Channel the modern history of aviation may be said to begin, and subsequent events are fresh in our memories. Merely to arrange them in their proper sequence, let us now summarize in briefest words the outstanding events of five crowded years.

Shortly before the Channel flight—in the summer of 1909—Henry Farman produced his famous biplane. G. B. Cockburn obtained his very earliest machine, and was the only Englishman to take part in the great Rheims Aviation Week, first and most famous of all flying meetings, the following August. The first Englishman (and he an Irishman !) to fly was J. T. C. Moore-Brabazon, who had piloted a Voisin in France some months before. Cockburn and Moore-Brabazon were two members of a little group of sportsmen, among them McClean, Ogilvie, Rolls and Grace, all members of the British Aero Club, who were responsible for the procuring of the Club's flying ground at Sheppey, the founding there of Short's famous aeroplane works, and for a vast amount of generous and patriotic labour which largely led to the introduction of flight into this country, and finally to its adoption in the army and navy. Flying meetings at Doncaster and Blackpool, exhibition flights by Paulhan near London, served to bring the new marvel before the British public, and the year closed with much popular interest and enthusiasm over aviation and its heroes.

But even before this momentous year of 1909 there had been flying in these islands, though few knew and fewer still regarded it. In the autumn of 1908, when the Wright Brothers first began to show their powers, a young man was experimenting with a triplane on Lea Marshes. His name was A. V. Roe, and scoffers called him 'Roe the Hopper' from the nature of the progress that his machine made across the grass. How could it have been otherwise when the engine that drove it was of only 9 horse-power! The marvel was it ever rose at all. The splendid Avroplanes already referred to are the lineal descendants of this first 'All British' aeroplane that hopped and jumped over the fields so many years ago.

And about the same time Cody at Farnborough was first getting off the ground in the big army biplane, the first officially observed flights of which were made in January 1909—seven months before Blériot flew the Channel. The picturesque figure of Samuel F. Cody will ever loom large among the pioneers of flight, for he was a big man, in stature, in genius and in heart. Originally of Irish stock, he hailed from Texas, and first appeared in a Wild West show; which fact, combined with his long hair and sombrero hat, led to the general but erroneous belief that he was, or at least was connected with, Colonel Cody, the original Buffalo Bill. His hobby was kite-flying, and presently he succeeded in introducing his big man-lifting kites into the British army and was given an official position at the Balloon Factory at Farnborough. While there he turned his attention to the construction of a large flying machine, and when his connection with the Balloon Factory came to an end he was presented with the aeroplane he had built and given leave to practise with it over Laffan's Plain. Before the year was out he had made the world's record by a cross-country flight of 40 miles

(*J. M. Bacon*)

CODY AND HIS KITE

(*J. M. Bacon*)

S. F. CODY IN 1903

round Aldershot. Incidentally he had cut his locks and become a British subject.

With the dawn of 1910 aviation was fully established in England and had clearly come to stay. The Royal Aero Club began to grant certificates to British aviators. By the end of the year they had granted 50, and the French Aero Club 300. In April came the London to Manchester race for the first *Daily Mail* £10,000 prize; an historic event full of dramatic surprises, which, although it resulted in the Frenchman Paulhan's win, yet placed Grahame-White upon that pinnacle of popular favour which he has occupied ever since. Flying meetings were held at Wolverhampton, Bournemouth, Lanark and elsewhere. Bournemouth was the scene of the first British aviation disaster—the death of Rolls, beloved pioneer, and magnificent flyer, an irreparable loss to the cause he had made his own. Robert Loraine, picturesque combination of actor and aviator, flew the Irish Channel. Sopwith made a magnificent non-stop flight on a Howard Wright biplane from Kent across France into Belgium. Chavez surmounted the Alps, 6600 feet high, at the Simplon Pass, and died pathetically in his hour of victory. Cecil Grace disappeared into the chill December mist brooding over the Channel, never to be seen again.

This year saw also the opening of two famous English Aerodromes, Brooklands and Hendon. It was a happy thought which converted the space enclosed by the famous motor track into a flying ground which has been the scene of so many great aviation events. It was a yet more enterprising scheme of Grahame-White and his company to evolve the London Aerodrome at Hendon, and while proving a highly successful commercial venture, it

(G. Bacon)

THE LONDON AERODROME, HENDON

undoubtedly conduced more than any other undertaking to popularize aviation in this country. It was reckoned a poor gate at Hendon before the War if less than 10,000 people were present on a Saturday or Sunday afternoon, and on Aerial Derby Days and such like the numbers rose to 60,000; so that a year's attendance had actually to be written in seven figures. Undoubtedly the 'Hendon habit' has grown upon the people of London, and with the exception of the great German flying ground of Johannisthal near Berlin, the scene of the utmost activity and preparation before the outbreak of hostilities, our London Aerodrome became at once the most popular in the world.

1911 was the year of the great cross-country races, Paris to Rome, Paris to Madrid, the Circuit of Europe, and, in our own country, the Circuit of Britain for the second £10,000 prize offered by that munificent patron the *Daily Mail.* 'Beaumont' or Lieutenant Conneau of the French navy, and Vedrines were the heroes of all these great races, and besides them Valentine and Cody alone completed the thousand-mile tour of the British Isles.

The outstanding features of 1912 were the appearance of the hydro-aeroplane and the waking up of the Government to the naval and military importance of flight. In March was founded the Royal Flying Corps, with military and naval wings. Military aeroplane competitions took place on Salisbury Plain in August. Aeroplanes played a recognized part for the first time in the army manœuvres, flying stations were established in different places, and the army and naval pilots began the magnificent work they have carried on so efficiently ever since. Wilbur Wright died of typhoid this year, Latham was killed by a buffalo in Africa, and accidents in the air cost too many valuable lives. On the Continent Vedrines flew at 100 miles an hour, Garros carried the height record up to 19,000 feet, and Fourny flew a Maurice

Farman biplane for 632 miles in 13 hours 17 minutes without stopping.

In 1913 long distance cross-country flights came more and more into fashion. In our own country, which is not suited for record making of this sort, army flyers flew from Montrose to Limerick, 375 miles, including the passage of the Irish Channel, in a day, and from Farnborough to Montrose without a stop. Non-stop flights were made from Paris to Berlin, from Paris to Bordeaux and back (646 miles), and 500 miles across the Mediterranean from France to Africa. Vedrines flew from France to Cairo on a Blériot monoplane, and Bonnier also on a Nieuport toured all across Europe and Asia Minor to Jerusalem and thence into Egypt.

Hawker very nearly completed the circuit of the British Isles on a Sopwith sea-plane with a Green engine. Pegoud introduced a wonderful new thrill by 'looping the loop' and flying upside down, in which he was very soon imitated by Hucks and Hamel, the first Englishmen to perform this now common feat. In August Cody was killed, with a passenger, and the whole world grieved the loss of a great and dearly loved pioneer. No other aviation fatality was so deeply and widely felt until, the following May, Gustav Hamel, easily first among British pilots for skill and popularity, attempted to fly the Channel on a foggy day, and, like Grace, passed from our ken never to be heard of more.

In those days Germany began turning her attention to aviation, military and otherwise, with characteristic thoroughness, so that by the middle of 1914 nearly all the world's big flying records, especially those requiring strength and staying power, had been captured by German aviators, flying German machines with German motors—*e.g.* 1350 miles flown in one day by Stoeffler, 21,450 feet (almost five miles) attained by Oelerich, and the Duration Record of 24 hours, 10 minutes, achieved by Boehm. They did not, however, beat the Speed Record of well over two miles a minute made by the Frenchman Prévost at the 1913 Gordon-Bennett Race.

In July 1914 the naval wing of the Royal Flying Corps was reorganized as the Royal Naval Air Service. The very start of naval flying was but three years previously, when Frank McClean lent three Short biplanes to the Admiralty to be used for instruction purposes, and Cockburn, at his own expense, taught four naval officers (all of high rank in the new service) to fly. To-day these gentlemen can be proud of what their patriotic and unselfish efforts have led to.

CHAPTER VI

FLYING IN PEACE AND WAR

HOW does a would-be pilot learn to fly?

First he selects his school and the particular kind of machine he wishes to be taught on, and the chances are that he will start with the 'school 'bus box-kite,'—popularly supposed to be safest and easiest to learn and control. As a first stage of instruction he is taken aloft as a passenger that he may realize what the near companionship of an extremely noisy engine feels like, and grow accustomed to the sensation of being in the air.

And this is not the awe-inspiring experience that some people imagine it. Aeronauts and aviators alike can testify that the fear of height, which affects so many of us on the earth, has no terrors aloft. The man who says he wants to jump out (but never does) of a fifth floor window, or whose knees become as cotton-wool when he peers over some beetling cliff, finds that he can look downwards from a balloon or aeroplane quite unmoved, and that 3000 feet is no more to him than 30. The fact is universal, though a curious exception is to be found in Henry Farman himself, who, in his racing days, flew habitually only a few feet above the grass, because he grew giddy and unnerved at any greater elevation.

Also the aviator is *not* sea-sick. Air-sickness undoubtedly does sometimes trouble pilots, of the bad-sailor variety, during long and stormy voyages when the machine rocks and pitches to excess; but it is comparatively rare, and generally means the flyer is exhausted or out of condition. Blériot, a proverbially bad sailor, made his first comfortable crossing the day he flew the Channel. The air-sickness that is akin to mountain-sickness only makes its appearance at heights very unusually attained by flying machines.

Next our tyro, who has studied the controls of the machine on the ground, is allowed to feel them in the air by placing his hand on the lever alongside his instructor's. In some aeroplanes there are duplicate controls, so that the pupil can take entire charge at times, while the teacher, when necessary, can correct his movements. In early days the controls of various machines varied widely. Some pilots steered with their feet and some did not. The Wright machine had a lever for each hand, the Antoinette two little wheels. Santos Dumont's comic-opera Demoiselle,—the 'Infuriated Grasshopper' that added so much to the gaiety of early flying meetings,—had the lever which controlled the warping of its bright yellow wings fastened by a tape to the pilot's waist-coat. Curtiss worked his ailerons by moving the back of his seat with his shoulders. These divers plans did not make for ease in learning to fly the different machines, and nowadays constructors have wisely come into line, and the controls are practically all alike for all machines, and so designed that the pilot in flight has to do just what his natural instinct would suggest.

With his feet he actuates a pivoted bar which moves the rudder, steering to the right by pushing his right foot forward, and to the left by moving the other. Everything else is done by means of an upright pillar surmounted by a handle or wheel. This pillar moves in all directions, and actuates elevator and ailerons or warp, and its movements are commonsense ones. To raise the nose of the machine the pilot pulls the lever towards him ; to dip it he pushes the lever away. If the left wing is falling he makes the movement of lifting it up, and pulls the lever slightly to the right ; if it is the right wing, he does the opposite. Always after each action he must bring the lever back to normal position. A very small movement suffices. Sitting behind the pilot in ordinary flight one hardly traces any motion of his steady hand as he delicately 'feels' his machine. This delicacy of touch is all essential to the skilful aviator ; light hands are as necessary to a flyer as to a jockey, a cook, or a pickpocket.

To rise from the ground the pilot has first to run his machine over the grass to gather speed. This is known as 'rolling,' or, more popularly, as 'taxi-ing.' With a biplane it is not so difficult to accomplish, but to taxi a monoplane in straight lines across the field, with tail well off the ground, takes some doing, for the machine has a disconcerting habit of spinning round and slipping sideways. 'A pup chasing his tail' is a familiar spectacle at a flying school, and not infrequently ends in 'breaking wood' (school expression). But not until he has mastered the art of rolling must the beginner attempt his first hop. At the Blériot school they make sure of this point by starting the pupil on a 'penguin'—a machine with engine not powerful enough to raise it from the ground. Afterwards he is promoted to a higher-powered ''bus' on which he can just rise; but not on any account must he try to turn in the air, in these early stages, or fly more than a few feet above the grass.

And this for the simple reason that he has yet to learn how to come down again. To make a good landing is the hardest part of his task. To do it he switches off his engine, and at the instant the motor stops, pushes the lever well forward, so that the machine begins to glide downwards. Just before touching the earth—when it seems that the wheels are almost on the ground—the lever must be gently pulled back so that the machine is 'straightened out' into a horizontal position for alighting. To gauge the exact moment when to do this requires judgment and experience, especially on a monoplane where the wings interfere with the pilot's downward view. If the glide is not checked in time the machine will hit the ground at too great a speed, and if checked too soon it will 'pancake.'

Popular aviation nomenclature is both picturesque and expressive. The light-hearted crowd who 'bung out the old 'bus' to 'do stunts' on, and say they suffer from 'cold feet' when any rare occurrence causes them alarm, describe as 'vol pancake' what happens when the machine comes to a standstill before it has reached the ground, and flops flat on its chassis. As usual it is the chassis that suffers and not the aviator. It is extraordinary how tremendously an aeroplane may be broken up and the pilot remain unhurt. This is because the pilot's seat being, generally, well in the middle, so much of the machine has to be smashed up before the force of the impact reaches it. The whole thing does not smash simultaneously, but first one portion and then another, so that the shock is 'damped,' and the aviator, even though he has fallen from 100 feet and his aeroplane is matchwood, may yet escape with nothing worse than a shaking.

A descent from the skies with engine shut off and the machine at its own gliding angle is the familiar 'vol plané.' To assume the angle is not difficult, for the well-designed aeroplane, if its nose is tilted down, will find it of its own accord. A descent at a steeper angle is a 'nose dive' or 'vol piqué.' An aviator will often execute this to pick up speed if he has lost way in the air, or if he is forced to descend on a particular space. To land a swift machine in a small area is test of the highest skill on the part of a pilot; but in our tidily kept island, where fields are small and fences many, it proves, over and over again, the only way to avert disaster.

Of possible accidents aloft there are a soul-satisfying variety. Some are due to atmospheric causes, of which wind naturally counts as chief. Nevertheless it is astonishing how wind has lost its terrors for the aviator, and how few accidents can be laid to its account. Five years ago Wilbur Wright refused to stir from his shed if the smoke of a cigarette did not rise straight upwards. A year later the whole world went wild with enthusiasm because Latham, at Blackpool, flew in a 40-mile wind. It was indeed a marvellous feat for those days, but now aviators will fly in almost any wind that blows; well aware that their properly balanced craft, although it will pitch and roll and wallow in the aerial waves, may yet be trusted, like a well-found ship, to recover its equilibrium.

Almost more disconcerting, because unexpected, are the perils of a hot, windless day—those suddenly encountered ascending and descending vertical currents known respectively as 'air pockets' and 'holes in the wind.' On entering one of these unseen perils all air resistance suddenly seems to cease, and the planes lose their support. As one famous aviator expresses it, it is 'like suddenly treading into a bog after walking on firm ground.' It may be an alarming experience, yet if the pilot is at a safe height, and keeps his head while his machine drops 50 feet or so, all is well, for he will then recover speed. The little eddies known as 'remous' are more entertaining than annoying, and are affectionately nick-named in the flying grounds where they resort. Increased speed and stability have shorn the atmosphere of most of its terrors.

Accidents due to faulty construction tend to become ever rarer with increased knowledge and care. There remain accidents due to the errors of the pilots themselves, and these, of course—human nature being what it is—can never be wholly eliminated. Nevertheless the inherently stable machine that looks after itself will go far towards achieving the impossible, as also the practice of flying high. In olden days aviators feared to do more than flutter along a few feet from the earth; now they know that their safety lies in height. High aloft they can do what they like with their aeroplanes—roll them over, fly upside down, slide down on their tails, upset them in every direction—confident that they have sufficient time to recover before reaching the ground. One of the most awkward things to occur in the air is a bad 'side-slip'—an expressive term which means that the aeroplane starts to fall sideways. A side-slip most frequently occurs when a pilot 'stalls' his machine—that is, attempts to make it climb at too steep an angle, or in other ways do more than it has power for. An overpressed machine flies 'cabré' or tail down, and as it loses its speed tends also to lose its lateral balance.

In a bad side-slip the machine may turn over so far that the elevator becomes upright and the rudder horizontal, so that their functions are reversed. Even then if the pilot but keeps his head all will be well, provided always he is flying high. Left alone, the properly designed craft will right itself ; and once the side-slip has become a nose-dive, the flyer should be able to resume command. ‘ Trust your machine ’ is one of the maxims drilled into a beginner. ‘ Don’t switch off your engine in a tight corner.’ ‘ Don’t try to rise when making a turn.’ ‘ Always land facing the wind.’ ‘ If the engine begins to fail, tilt the nose down immediately.’ All these are golden rules. It is reckoned that an average pupil learns to fly in about eight hours in the air. His tuition, however, is spread out over several weeks, because he is only allowed to practice for a few minutes at a time. Should he attempt more, he will infallibly get tired and muddled, and retrograde rather than progress. As one authority puts it—‘ Flying has to become instinctive, and you must give a new instinct time to grow.’

As to the cost of aviation. The price of an aeroplane —which may be made also to include a course of tuition upon it—can be anything from £400 to £1500. A good part of the price depends upon the engine. A single-seater machine with a 50 horse-power Gnome may be bought for about £700 ; a two-seater with 80 horse-power engine for £1000. The wages of a mechanic, cost of housing, insurance and repairs must all be considered, as well as the expense of fuel and oil, which, for a motor of 80 horse-power, would be about £1 for every hour of flight—averaging 70 miles. At present aviation is undoubtedly a costly sport, but every year now will see its expense lessen and its popularity increase.

It is not the place of this little work—actually passing through the press as the Great War broke out—to enlarge upon the mighty events which have shaken the world and altered the perspective of mankind. The part which aviation has played in the tremendous campaign is beyond all present estimate and cannot yet be fully gauged. The task of attempting to do so must be left to later days and wider knowledge. Meantime we can but attempt to summarize, in briefest words, some outstanding lessons which have already been taught us.

Flying machines have been used, since the commencement of hostilities, with the most prodigious effects, one of which, it is claimed, has been the prolonging of the action; since with the practical elimination of the 'fog of war,' owing to the fact that all movements of the enemy are now immediately known, the day of surprises and sudden concealed strokes is over, and war, as has been said, becomes less *kriegspiel* than a game of chess. This is one terrific and unlooked-for result. Of scarcely less far-reaching importance has been the immense assistance of the military aeroplanes in directing artillery fire, and the naval machines in detecting mines at sea. The effect, both moral and actual, of our aerial raids is hard to estimate —or possibly to over-estimate—even though they have demonstrated that it is as hard to aim correctly with a bomb from above as it is to hit a high-flying and swiftly moving machine with an anti-aircraft gun from below.

Many literally hair-breadth escapes from bullets and pom-pom shells, many actual duels in the air, have emphasized the supreme importance of speed and quick climbing in a war machine; qualities which appear to take precedence of all other advantages, even of stability and ease of control. This is understandable enough when we reflect that an aeroplane is within rifle and machine-gun range at 8000 feet altitude, and that machines have been riddled with bullets at 6500 feet. The armour-plating of aeroplanes does not appear to have been widely adopted, no doubt because it interferes with the two above-mentioned all-essential qualifications; but a protective sheet of steel is frequently placed in the pilot's seat as a very wise and well-proved precaution. The dropping of the deadly little steel arrows or 'flèchettes' from aeroplanes is a natural retaliation from aloft for unpleasant attentions from below.

The extraordinary immunity from accident of our naval and military pilots is one of the wonders of the War. Notwithstanding the vast amount of flying done, the dangerous conditions and the fact that flights are made in every sort of weather, it yet actually appears that an aviator on active service runs less risk of injury or death than an officer in any other branch of the service, except those on lines of communication. In explanation it has been brought forward that flying on the Continent is far safer than it is in Great Britain; and that an English pilot, educated to the treacherous gusts and air-pockets, and the hedges and walls of our wind-swept and tidy island, finds the uniform conditions and the wide obstacle-less plains of France and Belgium mere child's play to negotiate.

Nevertheless when all possible explanations are brought forward, the fact remains that good fortune has undoubtedly favoured us in our aerial endeavours; and this is the more remarkable when we reflect how badly we were equipped at the commencement of the War. According to expert calculation Germany opened hostilities with an aeroplane fleet of 1300 machines, doubtless all of her very best; France had about 800, many very ineffective; and Great Britain a scratch team of 100 or so. But how short a time did Germany enjoy her superiority. In sea-planes we have, of course, all along been *facile princeps*.

From the beginning the tractor biplanes have obtained and kept the lead over every other form of aerial craft, while the fast air-scouts are claimed as the salvation of our army. Monoplanes, though extremely useful for their special tasks, have not been so widely employed as biplanes, while vertical engines have rather gained the ascendancy over the rotaries as being more easy to silence.

The day has not yet dawned, as we write, for the revealing of many lessons that the Great War has taught. With the coming of Peace much will be made clear, and vastly increased knowledge and experience brought to bear in directions that will add materially to the welfare of mankind. Lessons learned on the battle-field will bear fruit in peace time, and the hour is surely very near when mails, and light merchandise, and travellers in a hurry, are borne by air from town to town and from country to country.

It is easy to speculate about the future of flight—as easy as it was to scoff at it ten years ago. Times change rapidly, and we have to cultivate short memories if only to forget our own false prophecies. This much at least is certain, that in subduing another element to himself man has accomplished a feat as great as when he pushed his first rude raft into the waves in prehistoric days, or set his earliest sail to explore the realms of the great unknown.

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